REPORT

ON

WATER POWER.

Report of the Committee of the Franklin Institute of Pennsylvania, appointed May, 1829, *to ascertain by experiment the value of Water as a Moving Power.*

The importance of accurate knowledge in relation to the effect of water as a moving power, and the defective state of information upon that subject, induced the Franklin Institute, in the spring of 1829, to determine that a series of experiments should be made, under its direction, upon the force of water applied by wheels; the experiments to be in detail, and upon a scale calculated to give confidence in the practical nature of their results. A call was to be made upon the members, and upon that portion of the public interested in the proposed researches, for aid, to enable the Institute to effect the object in view.

To obtain this aid, and execute the necessary experiments, a committee was appointed, consisting of members of the Institute. The number originally selected, was twelve; to these two members have since been added, the committee being now composed of fourteen members.

The appeal of the Institute to the liberality of its patrons, was readily answered, and the subscription lists of the committee soon contained an amount subscribed, sufficient to warrant them in preparing for the experimental part of their labours.

There is perhaps no subject connected with the extensive branch of mechanics, for which theory has done so little, as for that which considers the effect of water upon wheels; the different theories* advanced are at variance with each other, and with practice, so that the candid theorist confesses that the circumstances, attending the action, are of so complicated a nature as to baffle his powers of investigation. Experiment, then, can alone guide to results worthy of confidence.

The experimental inquiries in relation to water-wheels which have,

* Young's Analysis, or Gregory's Mechanics, vol. i. and 3d vol. American Philosophical Transactions.

deservedly, attracted most attention, are those of Smeaton.* The means of a single individual could not be competent to prosecute such a subject upon the scale required to make the results entirely practical, and we find the ingenuity of Smeaton labouring against the difficulties incident to the contracted dimensions of the apparatus which he was obliged to employ, and arranging with great skill and resource the best means to render serviceable the working models which were used in his experiments.

The experiments of Bossut,† which rank next in extent to those of Smeaton, were comparatively few, and were principally made upon the undershot wheel.

It would not be profitable to enumerate the isolated experiments made in different countries upon this subject, since the sum of the information which they convey is extremely small. Of late years this branch of inquiry has been but little prosecuted, and the committee are not aware that any experiments, except a few in France,‡ having in view a particular form of wheel, have been made, which tend to throw light upon the subject of their labours.

Such was the progress made in this subject when the Institute undertook it, with a view to obtain such results as should afford to the millwright a sure and safe guide in his practice, and thus contribute essentially to the promotion of one of the most important of the Mechanic Arts.

After frequent consultations of the committee, a plan of experiment was determined upon: the preparations of apparatus for executing this, occupied the autumn and part of the winter of 1829, and in the spring of 1830, the experiments were commenced. These occupied the committee until late in the following December, when the operations were finished for the season.

The committee consider that so little remains to be done to complete the proposed series of experiments, that they would not be justified in delaying their report, and that the results obtained should at once be placed before those to whose liberality the community are indebted for the opportunity of information upon this interesting subject.

It is hoped that means will not be withheld, by those who have not already contributed, to fill up the last subject upon the list of inquiries.

One of the most important questions which arose for the discussion of the committee, was the measure of power expended, and of effect produced, to be adopted in their investigations. They finally determined upon one which, while strictly correct in principle, was at the same time, from its simplicity and ease of application, well adapted to their purposes, viz. for the measure of the power applied,

* Smeaton's Experimental Inquiries, &c. (Taylor's Collection, 1794.)

† Détermination Générale de l'effet des roues mûes par le choc de l'eau, &c. 1769.

‡ Poncelet, Mémoire sur la roue Hydraulique verticale à aubes courbes. Ann. de Chim. et Phys. (1825.)

the weight of water expended multiplied by the height of the head, (kept invariable,) above the bottom of the wheel; and for that of the effect, the weight raised multiplied by the distance through which it was raised. In order that this measure of effect may be accurate, the friction and inertia of the machine must be considered. The friction was carefully ascertained by experiment and the proper allowance made for it, as will appear in the course of this report. Any resistance from inertia was avoided by causing the wheel, and of course the weight raised by it, to move, before beginning an experiment, with a velocity which would remain constant during its progress.

The committee were very favourably circumstanced in relation to the power to be applied in their experiments, having, by the vote of the city councils, at command, a head of water fully equal to that which it was deemed necessary to employ. The greatest head used in any experiment was twenty-three feet.

The building to contain the apparatus, was erected upon a site, put at the disposal of the committee by Messrs. Rush and Muhlenburgh, which was of sufficient extent to enable them to make, to the best advantage, the various arrangements required by the undertaking.

In order that the experiments may be more easily understood, the committee preface the detailed account of them, by a general description of the apparatus used, and of the methods of experimenting. This description is accompanied by three plates, of which plates I. and II. represent side views, and Plate III. gives an end view of the apparatus employed. The drawings refer to the arrangements made for experiment with the largest wheel used, that of twenty feet in diameter; alterations were made, from time to time, to adapt the apparatus to the use of the smaller wheels. The principal parts are designated by the capital letters, the subordinate parts by the small letters.* When any of the less important parts are shown much in detail in one of the plates, they are not always exhibited on the others. A scale to which the drawings were made is attached to the first plate.

The principal parts of the apparatus were, the forebay, or reservoir, for containing the water to turn the wheel, the frame supporting the wheel, the reservoir in which was collected and measured the water used, the wheel, and the means by which the weight raised and the space through which it was raised were measured.

These will be described in the order in which they have just been mentioned.

The Forebay.

The forebay, A, B, C, D, E, F, (Plates I. and II.) was constructed of timber frame work, consisting of upright posts secured at the bottom

* There are two kinds of small letters used, the *Italic* and the Roman, the small *Italic* letters are used until the whole number is exhausted, when recourse is had to the small Roman letters.

and top by being tenanted into cross-sills and caps: the cross-sills were raised about seven feet from the ground, being supported by vertical posts, (as shown in the drawing,) resting on timbers placed upon the ground. The frame, above described, was lined with planks, and was secured from yielding to the pressure of the water at points between the cross-sills and caps, by strong iron bolts which passed through each pair of posts, on the opposite sides of the forebay, and were placed at intervals increasing as the distance from the top of the forebay diminished. The planking on the back end of the forebay was supported at the middle of its breadth by an upright post, B, C, secured by bolts to the adjacent cross-sill and cap, and, at proper intervals between them, to cross timbers, H, H′, &c. (Plate I.) within the forebay, and supported by the planking of the sides. The floor of the forebay was laid upon the cross-sills into which the uprights of the frame work tenanted. The front end, A, F, (Plates I. and II.) projected beyond the centre of the wheel, and had, within, a breast, K, K′, K″, K‴, (Plate I.) made to fit accurately the periphery of the wheel, except near the top, (from K to K′,) where an interval was left between the breast and wheel, to facilitate the discharge of air from the buckets. The breast was secured from springing, and made moveable at pleasure, to adapt it to the use of the smaller wheels, by accurately fitting the planks composing it to circular cleats, (not shown in the figures,) spiked to the forebay on the concave side of the breast; to press the planks against these cleats, a second set was spiked to the forebay on the convex side of the breast, between which and the breast-planks wedges of the proper form were tightly driven.

In the breast, apertures closed by gates were provided at different points, through which to let the water upon the wheel. The sluices, or chutes, connected with the apertures, were narrowest at the parts where the water issued, and delivered the water to the buckets nearly in the directions of tangents to the wheel at the several points of emission. The lowest, or undershot aperture, was not in the breast, but in a vertical partition, *a*, *a′*, (Plate I.) extending from the floor of the forebay to the breast, the bottom of the aperture being on a level with the lowest point of the wheel; this aperture was closed by a gate sliding in vertical grooves, and the water flowing through it was delivered by a sluice, narrowing towards the point of emission, in a tangential direction to the lowest point of the wheel. The overshot gate at K, discharged the water immediately over the centre of the wheel. The details of drawing and description in relation to the construction of the gates and apertures, to the methods of gauging, &c. will be given when the committee treat of the action of the wheel under the several circumstances of experiment.

Water was admitted to the forebay through two iron pipes, L, L′, and M, M′, (Plates I. and II.) of 6 inches in diameter, passing through the bottom of the forebay, and connected with the pipes from the city water works: the supply was regulated by two stop cocks, at *b* and *b′*, (Plate I.) acted upon by levers of the second order, having their fulcra at *c*, and *c′*, which by the intervention of two vertical

rods, d, d', and e, e', were connected with the levers, d', g, and e', g'; the common fulcrum of the levers, d', g, and e', g', was at f, and their handles, g and g', near the end of the forebay, were conveniently placed in relation to an assistant, on the upper floor, G, G', whose duty it was to regulate the supply of water. The upper ends of the water pipes were made to project 18 inches above the floor of the forebay, that the rush of water from them might not produce irregularity in the action of the undershot aperture.

To show the level of the water within the forebay, a float, h, (Plate I.) moving freely in vertical guides, was placed at the back end: to this float a graduated tape line, h, h', h'', was attached, passing over a pulley, h', and kept tight by means of a weight, h''; an index, i, served to show upon the tape line the head of water sought. A valve, k, (Plate II.) in the bottom of the forebay, could be opened by depressing the end, k'', (Plates I. and II.) of the lever k', k'', and served to allow the escape, when required, of the water, through the trunk, I, to the waste trough.

The levers for opening and closing the various gates in the breast were attached to the top of the forebay, in such positions as best to answer the ends to be accomplished by them. As the drawing would be much confused by an attempt to represent all these levers, but one system is shown, namely, that l, l', l'', K, (Plate I.) for opening the overshot gate; the lever, l, l', was oblique to the side of the forebay; by turning the handle, l, to the left, the fulcrum being at m, the end l', and, (by means of the connecting rod, l', l'',) the end l'', of the lever, l'', K, were turned to the right, which, the fulcrum of l'', K, being at m', opened the gate at K.

Frame supporting the Wheel.

N, O, P, Q, represents the frame supporting the water-wheel: this frame was formed on one side of the wheel, (Plates II. and III.) by a double row of uprights, and on it the head block, n'', n''', (Plate II.) was placed to sustain the plumber block, o', on which one end of the axis of the wheel rested; on the other side, (Plates I. and III.) a single row of uprights braced from the floor, and connected at top and bottom, formed the frame; this was surmounted by the head block, n, n', upon which rested the plumber block, o, carrying the axis of the wheel. This frame was disconnected from the forebay.

Reservoir for collecting and measuring the water used, Tail race, &c.

A reservoir, R, S, T, Q, (Plates I. II. and R, R, Q, Q, Plate III.) for collecting and measuring the water used in experiment, was made by planking the interior of part of the frame just described; the sides and ends of the reservoir were carried to the height of six feet, and the floor was laid upon the cross-sills into which the uprights of the frame were tenanted.

This reservoir having been formed accurately into a rectangular prism, its capacity was calculated by measuring the length, breadth, and depth: to test the accuracy of the result, the reservoir was filled, up to a certain level, with water carefully weighed, the number

of pounds which the whole reservoir would contain calculated, and found to differ but 20 lbs. in 30,000, from the weight obtained by means of the capacity.

To indicate the level of the water in this reservoir, with a view to determine the quantity used in any experiment, a hollow tin vessel, *p*, *p'*, (Plate I.) was used as a float; a tube passed through the axis of the float, forming a stem, which was allowed to slide freely in a vertical direction upon an iron rod, or guide, attached to the bottom of the reservoir: the stem, *q*, *q'*, of the float extended to a convenient height above the lower floor, N, O, and was graduated into divisions, each of which represented a quantity of water within the reservoir of 1000 lbs. in weight. A light bar of iron, *r*, *r*,' was attached to the upper timber of the wheel frame, having at its upper end, *r*, a loop embracing the stem of the float; to this loop was affixed a sliding plate of brass, *r*, *r''*, the edge of which could readily be placed opposite to that mark, on the float rod, which might happen to be next above the loop; this mark then served as a point from which to estimate the quantity of water used in any experiment without, before commencing, actually emptying the reservoir. The number of divisions on the stem of the float which had passed the top of the slide during an experiment, showed within certain limits of accuracy, the quantity of water which had entered the reservoir; but for greater nicety of determination, a gauge plate minutely divided was applied to the top of the slide, by the use of which the quantity of water in the reservoir could be obtained to within 5 lbs.

The water after leaving the wheel was conducted through a slightly inclined tail-race, U, R, to the reservoir. To prevent agitation of the surface of the water, within the reservoir, which would have resulted from the fall of water introduced from the tail-way, a flume R, *s*, *s'*, Q, (Plates I. II. and *s*, *s*, *s'*, *s'*, Plate III.) of a square section, was constructed, extending from the race nearly to the bottom of the reservoir, between which and the termination of the flume the water must necessarily pass; there was also a platform of light boards, nearly as large as the floor of the reservoir, placed within, which rose and fell with the surface of the water: these precautions so far preserved the float from oscillation, that the operator could obtain without delay by inspecting the gauge rod, the weight of water collected in the reservoir.

To empty the reservoir, a waste valve, *t*, (Plates II. and III.) was placed at one end; this valve could be opened by the lever, *t'*, *t''*; (Plate II.) having its fulcrum at *t'''*, acting upon the valve by the intervention of the rods, *t' t*^{iv}, *t*^{v} *t*, (Plate III.) and lever *t*^{iv}, *t*^{v}; it was raised above the floor so that the reservoir might never be entirely emptied, and that thus a level would always be afforded from which to reckon the quantity of water which entered during any experiment.

As only the water used in experiment was to be admitted to the reservoir, a valve *u*, *u'*, (Plates I. II. and III.) 15 inches in breadth, and in length equal to the breadth of the wheel, was placed in the floor of the tail-race; this valve when open, allowed the water from the wheel

to fall into a trough u, u, v, v', v'', v''', (Plate III.) which conducted it on the outside of the reservoir, by the trunk w, w', (Plates II. and III.) to the waste trough. Guide boards were placed in the tail-way on each side of the valve, that all the water might pass through it when open. The closing and opening of this valve were effected by the action upon the stem x, x', (Plates I. and III.) of a series of levers, (Plates III. and II.) x', x'', y, y', y'', z, connected by vertical rods x'', y, and y', y'', and terminating in the stem z, z', on the side of the forebay shown in Plate I.; by means of a handle, z'', attached to this stem the operator on the first floor, N, O, O', was enabled to work the valve. When the valve was closed, the water flowed over it to the lower end of the tail-race, whence it passed, in the manner already described, to the reservoir. A bell, a, (Plate I.) attached by a spring to the stem z, z', ringing when the stem was moved, served to give notice of the closing or opening of the tail-way valve, that is of the beginning or end of an experiment. As in closing the valve, in commencing an experiment, the small quantity of water between it and the wheel, not used in the experiment, entered the reservoir, so on opening it, at the conclusion, an equivalent quantity of the water which had been used ran to waste.

The water carried up by the wheel when in motion, was returned to the tail-race by the guard, b, b', u', (Plates I. II. and III.) placed for this purpose, and conducted to the reservoir, or allowed to run to waste according to the position of the valve.

Water-Wheel.

V, W, U, X, (Plate I.) represents the water-wheel used during the first series of experiments; this wheel was 20 feet in diameter, and 20 inches in breadth, being 16 inches, in the clear, between the rims, or cants. The rims were attached to the arms in the usual manner. The axis of 12 inches in diameter, into which the arms entered, was surrounded, for a certain portion of its length, as shown in Plate III., by a barreling of 24 inches in diameter, the gudgeons, $3\frac{1}{2}$ inches in diameter, turning upon brass bearings, fitted into cast iron plumber blocks; the whole rested on the head blocks n, n', n'', n''', (Plates I. and II.) capable of sliding upon the upper beam of the frame supporting the wheel, by which arrangement the wheel might be removed from the breast when alterations were required.

On the inside of the head block, at n, Plate I., an iron pin was fined, connecting two straps, also of iron, in the manner of a joint hinge; these straps embracing the barreling of the shaft had their ends, d and d', connected by a wooden lever, d', d'', turning upon a fulcrum, d''', equi-distant from the ends which the lever connected; the pin forming the fulcrum passed through a post attached to one end of the head block: by depressing the end d'', of the lever, d', d'', the straps were caused to press against the barrel with such force as to regulate, at the pleasure of the experimenter, the retrograde movement of the wheel produced by the descent of the weight which had been raised in any experiment; by elevating the same end of the

lever, the straps were removed from contact with the barrel, which was thus permitted to revolve freely.

The buckets of the wheel having been varied in the different experiments will be described in detail in an after part of this report.

Apparatus relating to the Measure of Effect.

Y, Y′, Y″, and Z, Z′, Z″, (Plates I. and III.) represent two masts, or heavy posts, one of which was stepped upon the ends of two adjacent cross-sills of the forebay, at Y, the other, at Z, upon a strong piece of timber, bolted to the side of the frame, supporting the wheel. From the cap, Y″, Z″, (Plate III.) connecting these posts, were suspended two iron pedestals, e, e′, and f, f′, in which, in brass bearings, turned the gudgeons of a roller, or drum, e′, f′; the gudgeons were 1 inch and $\frac{7}{8}$ths in diameter. The drum, $16\frac{1}{2}$ inches in diameter, was covered with hoop iron, to prevent its abrasion by the chain which passed over it. The chain was attached at one end to the barreling of the shaft of the water wheel, and passing over the drum above, the other end, g, was fastened to a basket, g, g′, of iron in which were placed the various weights used in the experiments. To prevent inequality in the weight raised during any part of an experiment, from the winding of the chain upon the barrel, a similar chain, the lower part of which always rested on the ground, was fastened to the bottom of the basket.

The chain was kept from riding and chafing, as it wound upon the barrel, by depressing slightly the end f′, of the roller, thus giving the chain a tendency to move, in winding, towards the depressed end. The chain was brought back to its original position, at the higher end of the drum, during the descent of the basket, by inclining that part between the drum and barrel in an angle, to the axis of the drum, measured towards the elevated end, less than a right angle: to give this inclination a pulley, k, (Plates III. and I.) was fixed in an iron frame, k′, k″, capable of sliding in horizontal guide grooves; by drawing the frame towards l, the pulley was made to press against the chain effecting the object proposed. The iron frame, k′, k″, was drawn towards l, by a rope, one end of which was attached to the frame at k″, while the other passed over a fixed pulley, l, and was attached to an axle turned by the arms m, m′, and m, m″. The frame was carried back to the end, n, when the power ceased to be applied at the arms, m, m′, m, m″, by a weight n′, acting by the rope, n′, n, k′, passing over the pulley n, and attached to the frame at k′.

The measure of effect adopted was, as has been stated, the weight raised, and the height through which it was raised; to determine this height a mark was fixed to the chain at a point convenient for beginning the experiments, and a second to serve as a point of termination. To enable the operator to judge accurately of the arrival of these points on a level with his eye, an indicator, p, p′, p″, (Plate I,) being a miniature crane, was attached to the side of the forebay frame, the horizontal arm being placed at the proper height above the lower floor O, O′; the habitual position of the indicator was, as

shown in Plate I, with the horizontal bar resting against the forebay frame. Just before the arrival of the lower mark upon the chain, at the level of the indicator, it was turned at right angles to the side of the forebay; when the mark reached the indicator, the stem, z, z', of the lever for manœuvring the gate in the tail race, was raised into the position represented in the figures, ringing the bell a; the ringing of this bell, and the closing of the tail-way valve, being simultaneous, the precise instant was thus marked at which the water began to be admitted to the reservoir. On the arrival of the second mark at the indicator, the stem, z, z', was drawn down, by means of the handle z'', again ringing the bell, and marking the time of the conclusion of the experiment, namely, that at which the water was allowed to run to waste by opening the valve in the tail-race: the stem, z, z', was kept in its new position, by inserting the baton q, beneath the lower edge of the rest, q', q''.

A very accurate time-piece, with the dial graduated to half seconds, completed the apparatus.

Method of Conducting the Experiments.

A general statement of the methods of experimenting will now be given.

One person was stationed upon the upper platform, specially charged with regulating the head of water in the forebay: this he did by means of the levers d', g, and c', g', (Plate I,) controlling the stop cocks, b, and b', in the supply pipes, or when the level was too high, by letting off as much water as was required to reduce it, through the waste valve k, Plate II; the head was ascertained by the float h, (Plate I,) tape line, h, h', h'', and index, i, already described. The same person being always employed in this duty was, by practice, enabled to preserve a required head, subject to a variation of not more than a quarter of an inch, during any one experiment. The same operator opened and closed the gates for letting the water upon the wheel, and regulated the position of the chain during the descent of the basket so as to bring it back to the elevated end of the roller, by turning the arms m, m' and m, m'', connected by the rope l', l, k'', with the slide, k', k'', carrying the pulley, k, (Plate III.)

A second assistant was placed upon the lower platform, N, O, O', (Plate I,) who had in charge the regulation of the break or friction strap, and the closing or opening of the tail-race valve, u, u', for collecting, or suffering to run to waste, the water used by the wheel; he also placed the proper weights in the basket, allowed the escape of the water from the reservoir when necessary, &c.

A third person attended to note the circumstances of each experiment, to observe the time occupied, the quantity of water in the reservoir as shown by the gauge rod, and to make the necessary calculations.

When an experiment was to be made, the moveable plate r, r'', (Plate I,) of the reservoir gauge was set to the mark on the gauge rod next above the loop. One of the gates for letting the water

upon the wheel, was then opened, and the wheel suffered to revolve, with a full supply of water, until the basket was raised sixteen feet; by this time all the moving matter had acquired an equable motion, and the first mark upon the chain coincided with the indicator, p, p'; at this instant the second operator closed the tail-race valve, in doing which he rang the bell, a, the signal for the third operator to note the time. The first operator now carefully kept the water in the forebay, at a constant level. The water used by the wheel passed into the reservoir, R, S, T, Q, until the second mark on the chain, coincided with the indicator, when the second operator opened the tail-way valve, at the same time causing the bell, a, to ring, thus giving notice to the third operator to mark the time, and to the first to close the aperture admitting water to the wheel, and to stop the influx of water into the forebay. The chain was then drawn back, by the pulley and slide described, as the weight descended retarded by the friction strap. By the time the weight had arrived at the lower platform, the surface of the water within the reservoir was at rest, the amount there collected was ascertained, and a memorandum of it placed upon the minutes.

Having given a general description of the apparatus used in the experiments, the Committee proceed to state the methods employed in estimating the resistance arising from friction.

Experimenters have differed in the results of their investigations of the laws of friction. It results from the experiments of Coulomb, that the friction at the axle of a wheel, or of a roller, varies in the direct ratio of the pressure upon the axle, except in extreme cases. The late experiments of Mr. Rennie* indicate that when unguents are used, the ratio of friction to pressure is not the same for different pressures, the variation depending upon the nature of the unguent and the amount of pressure applied.

The Committee deemed it necessary, therefore, to determine with the apparatus to be used in their experiments, and under the probable loads to which it would be subjected, the relation between the friction and weight. It will be seen that this labour was much abridged by the fact that the experiments showed the ratio of friction to pressure to be constant, within the limits required by the investigations.

The experiments of Rennie have satisfactorily established that the friction of an axle remains the same, in proportion to the weight, under different velocities.

The frictions to be estimated by the committee, were those at the axis of the water wheel, and at the axis of the roller, or drum, above the wheel.

To ascertain the amount of friction at the axis of the wheel, a cord was wound about the barreling of the shaft; to this cord was attached a weight varied until it just maintained a velocity of six feet per second in the periphery of the wheel: the weight, thus found, gave the friction upon the gudgeons, when pressed by the weight of

* Transactions of Royal Society of London, Part I. 1829, pp. 163 and 164; or Journal of Franklin Institute, Vol. V. No. 2.

the wheel together with the weight representing the friction. The pressure upon the gudgeons being increased, by attaching masses of lead to the wheel at equal distances from, and on opposite sides of, the axis, the friction was found in the cases tried, viz. those within the probable limits of the weights to be borne in the experiments, to be proportional to the weight sustained by the gudgeons of the wheel. The proportion of friction to weight was found to be one and a half per cent.

The friction at the axis of the drum was ascertained by passing a cord over it; to the ends of this cord weights were attached, and the additional weight necessary to cause either extremity to descend with a uniform velocity, gave the amount of friction. By varying the weights at each end of the cord, it was found that in this case, as in that of the wheel, the friction was proportional to the weight borne by the gudgeons, and that the proportion of friction to the weight was one and a half per cent. This latter circumstance tends, as well as the former, to simplify the calculations relating to friction. The weights having been raised by the wheel through the intervention of a chain passing over a drum above, it is evident that the axis of the wheel was drawn upwards with a force due to the tension of the chain between the axis and the drum, that is, to the weights attached to the chain, thus diminishing the pressure upon the axis of the wheel, and lessening, in consequence, the amount of friction; but this tension increased the pressure upon the axis of the drum, and since the friction at that axis, by a given weight, was the same as that at the axis of the wheel, these two opposite effects balanced each other, and there remained the friction due to the weight applied to the chain.

As reference is necessarily made, in the calculations which follow, to the centres of gravity of the loaded parts of the wheel, it may not be amiss to state the manner in which these points were determined. The general remarks apply to the several wheels used, but the details refer to the largest wheel.

The water was supposed to be distributed uniformly over the loaded part of the wheel, a supposition very nearly accurate when the buckets are numerous and the wheel works within a close breast. A section of the wheel perpendicular to the axis, and midway between the rims, being taken, the weight of the water was supposed to be concentrated in that part of the periphery of a circle, a mean between the circles containing the interior and exterior edges of the buckets, which corresponded to the loaded part of the wheel. In Fig. I, Plate V, *a*, *b*, *g*, represents the semi-circumference of this circle, a mean between the semi-circumferences A, D, F, I, and K, L, M, of Fig. I, Plate IV, the radius being 9 feet 9 inches in the case figured, viz. that of the large wheel. To find the arcs corresponding to the loaded portions of the wheel, this circle was described upon a large scale; the several points answering to those at which the water, admitted to the wheel through apertures Nos. 1, 2, &c. (Fig. I, Plate IV,) first struck the wheel, were laid down, as at *a*, *b*, *c*, *d*, *e*, and *f*, (Fig. I, Plate V,) the lowest point of the wheel, *g*, being taken as the

point at which the water was discharged, the arcs sought were *acg*, *bcg*, *cdg*, *deg*, *efg*, and *fhg*. The centre of gravity of each of these arcs, was then found by the usual method. The diagram shows the chords, *ag*, *bg*, *cg*, &c. from which the lengths of the arcs were obtained, the lines bisecting these chords, and upon which the centres of gravity of the arcs are to be found, *ci*, *ck*, *cl*, &c., and upon these lines the points corresponding to the centres of gravity, viz. G, G′, G″, G‴, G^{iv}, G^{v}. By drawing lines parallel to *ag*, from the points thus found, the distances from the axis of the wheel, obtained by calculation, are shown upon the scale traced in the figure.

We shall now give the calculations of the amounts of resistance from friction, in the wheel and drum, under the various loads to which they were subjected in the course of the experiments.

First. Constant *inactive* weight borne by the gudgeons of the wheel and drum during the experiments.

Weight of the water wheel, -	2200 lbs.	
The whole weight of the chain was 318 lbs.; of this an average weight of 34 lbs. (20 feet of the chain,) rested upon the ground during each experiment, and that part of the chain between the barrel of the shaft and the ground (20 lbs.) acted to resist the motion of the wheel: deducting, therefore, 54 lbs. from the weight of the chain, we have for the constant *inactive* weight upon the gudgeons of the wheel and drum, derived from the chain, -	264 ,,	
Weight of the drum, - -	200 ,,	
Total constant inactive weight, -	2664 lbs.	
The friction upon this, at one and a half per cent, is - - - -		39.96 lbs.

Second. Constant weight *resisting* the motion of the wheel, which was borne by the gudgeons of the wheel and drum.

That part of the chain which was between the barrel of the shaft of the wheel and the ground, - - - -	20 lbs.	
The iron basket used to contain the weight,	126 ,,	
Three bars of lead, weighing together	111 ,,	
Total constant resisting weight, - -	257 lbs.	
Friction due to this weight at one and a half per cent, - - - -		3.85 lbs.
The total friction derived from the *constant weight*, is, therefore, - -		43.81 lbs.

The amount of friction due to the constant weight having been thus found, we proceed to the numbers which varied with the weights

added in the experiments, and with the points of admission of water to the wheel.

CHUTE No. 1. (Fig. I, Plate IV.)

The centre of gravity of the water in the buckets of the wheel when supplied by this aperture, was 6.207 feet from the axis, and the barrel about which the chain was wound was 1 foot from the same axis; hence to raise 257 lbs. the constant resisting weight, and overcome a friction of 43.81 lbs. the constant friction just found, required a weight of water of - - - -	48.46 lbs.	
The friction due to this weight, is -		0.73 lb.
Constant friction derived above, - -		43.81 ,,
Whole amount of friction overcome in raising the constant weight of 257 lbs. -		44.54 lbs.
To find the additional friction due to each of the bars of lead which were used as weights, we have,		
Weight of the bar, - -	103.00 lbs.	
To balance this weight and the friction due to it, (103 lbs. + 1.54 lb.) or 104.54 lbs. required, at 6.207 ft. from the axis, a weight of water of - - -	16.84 ,,	
Total, - - -	119.84 lbs.	
Friction for each bar of lead, being that upon the weight just found at one and a half per cent. - - - -		1.80 lbs.

CHUTE No. 2. (Fig. I, Plate IV.)

In this case the centre of gravity of the water in the buckets, was 7.01 feet from the axis, to raise 257 lbs. and overcome the friction of 43.81 lbs. required, - - - -	42.91 lbs.	
Friction due to this, - -		0.64 lb.
Constant friction as above, - -		43.81 ,,
Total friction due to constant weights, -		44.45 lbs.
For each additional bar of lead,—		
Weight of the lead, -	103.00 lbs.	
To balance this weight and the friction due to it, - - -	14.91 ,,	
Total, - - -	117.91 lbs.	
Friction for each bar of lead, -		1.77 lbs.

CHUTE No. 3. (Fig. I, Plate IV.)

The centre of gravity of the load was in this case 6.58 feet from the axis: to raise 257 lbs. and overcome a friction of 43.81 lbs. required, - - -	44.72 lbs.	
Friction due to this, - -		0.68 lb.
Add as before, - - -		43.81 „
Total friction due to constant weight, -		44.49 lbs.
For each bar of lead which was added,—		
Weight of the lead, - -	103.00 lbs.	
To balance this weight and its friction,	15.88 „	
Total, - - -	118.88 lbs.	
Friction due to each bar, - -		1.78 lbs.

CHUTE No. 4. (Fig. I, Plate IV.)

The centre of gravity of the load was 5.89 feet from the axis: to raise 257 lbs. and overcome the friction of 43.81 lbs. required -	51.07 lbs.	
Friction due to this, - -		0.76 lb.
Add as before, - -		43.81 „
Total friction due to constant weights,		44.57 lbs.
For each bar of lead added,—		
Weight of the lead, - -	103.00 lbs.	
To balance this weight and its friction,	17.74 „	
Total, - - -	120.74 lbs.	
Friction due to each bar, - -		1.81 lbs.

CHUTE No. 5. (Fig. I, Plate IV.)

The centre of gravity of the load was 4.84 feet from the axis: to raise 257 lbs. and overcome a friction of 43.81 lbs. required -	62.15 lbs.	
Friction due to this, - -		0.93 lb.
Add as before, - -		43.81 lbs.
Total friction due to constant weights, -		44.74 lbs.
For each bar of lead added,—		
Weight of the lead, -	103.00 lbs.	
To balance this weight, and its friction, required, - - -	21.59 „	
Total, - - -	124.59 lbs.	
Friction due to each bar, - -		1.87 lbs.

The water delivered through Chutes Nos. 5 and 6, acts principally

by impulse, at nearly the extremity of the radius of the wheel; this remark applies to No. 5, more exactly, when the head of water above the aperture is considerable; for all heads above four feet, the centre of force was taken at nine feet from the axis.

Not only is the arm of the lever, upon which the water from apertures Nos. 5 and 6 acts, greater, but the direction of the impulse does not coincide with that of gravity, hence the amount of pressure is not the same with the weight, or the ratio of friction to the weight must be diminished. The friction for Chute No. 6, and for Chute No. 5, when the head is more than four feet, may be taken at three-fourths per cent of the weight. The amount of friction being but small, nice calculations upon these points would have been entirely useless.

CHUTE No. 5.—When the head is above four feet.

To raise 257 lbs. and overcome a friction of 43.81 lbs. requires a weight of water, at 9 feet from the axis, of - -	33.42 lbs.	
Friction upon this at three-fourths per cent,		0.25 lb.
Add as before, - - -		43.81 ,,
Total friction due to constant weights, -		44.06 lbs.
For each additional bar of lead,—		
Weight of bar 103 lbs. friction at one and a half per cent, - - -		1.54 lbs.
To balance this weight and its friction, required - - -	11.62 lbs.	
Friction upon this at three-fourths per cent, -		.09 ,,
Friction due to each bar, - -		1.63 lbs.

CHUTE No. 6. (Fig. I, Plate IV.)

The friction was sensibly the same with that for Chute No. 5, when the head at that chute was above four feet. Hence, the friction due to the constant weights was, - -		44.06 lbs.
And the friction for each bar of lead, -		1.63 lbs.

CHUTE No. 7.—Undershot.—(Fig. I, Plate IV.)

Here the water acting entirely by impulse, the centre of force may be assumed at 9.75 feet from the axis.

To raise 257 lbs. and overcome a friction of 43.81 lbs. required, at 9.75 feet from the axis, a weight of -	30.85 lbs.	
Friction upon this at three-fourths per cent,		0.23 lb.
Add as before, - - -		43.81 lbs.
Total friction due to constant weights, -		44.04 lbs.
For each bar of lead added,—		

Weight of bar 103 lbs. Friction upon this at one and a half per cent,		1.54 lbs.
To balance this weight and its friction, required	10.72 lbs.	
Friction upon this at three-fourths per cent,		0.08 ,,
Friction due to each bar,		1.62 lbs.

The foregoing calculations were applicable until nine leads, (927 lbs.) had been added to the constant weight in the basket; this weight suspended the end, *o*, (Plate III. Vol. vii.) of the shaft of the wheel. Any addition of weight to this, pressed the gudgeon against its cap with a force which was to the tension of the chain produced by the weight added, as the distance from the point at which the chain acted to the other gudgeon, (*o'*, Plate III.) was to the whole length of the shaft. The whole length of the shaft was 9.25 feet, the point of suspension 1.66 feet from the end *o*, of course 7.59 feet from *o'*. If one lead of 103 lbs. be added to the nine supposed in the basket, the force drawing the shaft upwards will be 103 lbs. together with its friction 1.54 lbs. or 104.54 lbs.; to find its effect upon the gudgeon, *o*, we have the proportion, 9.25 : 104.54 : : 7.59 : 85.78, the force, in pounds, with which the gudgeon, *o*, is pressed against its cap. Subtracting this weight from 104.54 lbs. the total weight from which both the gudgeons are relieved, there remains 18.76 lbs. the force tending to draw the gudgeon *o'* upwards, or the weight from which that gudgeon was relieved.

To ascertain the friction when more than nine leads were added to the constant weight in the basket, we have,

Friction due to the weight of each lead of 103 lbs.		1.54 lbs.
Tension of chain between axis of wheel and drum pressing upon the gudgeons of the drum,	104.54 lbs.	
Force with which gudgeon *o* was pressed against its cap, 85.78 lbs.		
From this deduct the weight from which the gudgeon *o'* was relieved, 18.76 ,,		
There remains the pressure upon the axis of the wheel,	67.02 lbs.	
Total pressure upon the gudgeons of the wheel and drum, by the addition of each lead after the ninth,	171.56 lbs.	
Friction upon this at one and a half per cent,		2.57 lbs.
Friction due to each lead after the ninth, exclusive of the water required to overcome this friction,		4.11 lbs.

When the water was admitted to the wheel through Chute No. 1.

To overcome 103 lbs. and the friction of 4.11 lbs. or 107.11 lbs., required, at 6.207 feet from the axis, - -	17.26 lbs.	
Friction due to this, - -		0.26 lbs.
Friction just determined, - -		4.11 lbs.
Total friction for each lead after the ninth,		4.37 lbs.

The friction due to the weight of water necessary to balance each additional lead and its friction, was so small that its variations when the water was applied through the different chutes, could with propriety be neglected. The variation from the friction given by Chute No. 1, in an extreme case, that of Chute No. 5, at a friction of one and a half per cent, is but .07 of a pound. The friction for each lead after the ninth, was, therefore, taken at 4.37 lbs. at all the chutes.

The necessary details in relation to the friction of the several smaller wheels, will precede the account of the experiments made with each of them.

Before passing to a detail of the experiments, it may assist the reader to give a brief statement of the principal points to which the researches of the committee were directed.

The first and most general subject for determination, was the mode of applying any given head of water, so as to produce the greatest ratio of effect to power expended.

To ascertain this point, regard was to be had to, and variations made in, the head of water, the diameter of the wheel, the point of application of the water to the wheel, the size of aperture through which water was admitted to the wheel, the form of gate which was applied to the chute, the form, number and position of the buckets, and the velocity of the wheel.

The second object was to determine for a given wheel, the form of bucket which would admit of the application of the greatest quantity of water, giving the maximum amount of effect, without diminishing the ratio and effect to power expended.

Wheels of four different diameters were used in the experiments; No. I, had a diameter of 20 feet, No. II, of 15 feet, No. III, of 10 feet, and No. IV, of 6 feet. A particular description of each wheel will precede the statement of the experiments made with it.

The experiments were begun with wheel No. I; this wheel, as has been stated in the general description, was 20 feet in diameter, 20 inches in breadth, and 16 inches, in the clear, between the cants, which were 6 inches deep.

The buckets first attached to this wheel were *elbow buckets*, these were $15\frac{1}{2}$ inches deep, with a width of elbow of 3 inches, and an opening at the throat of $2\frac{5}{8}$ inches. In sector A, B, C, (Plate IV,) these buckets are represented, *e*, *e*, &c.: the number around the whole circumference was fifty.

In the bottom of each bucket an air vent was provided, $\frac{3}{8}$ths of an inch wide and occupying the breadth of the wheel; each vent was placed in the upper part of the bucket, to which it belonged, as near as practicable to the elbow of the preceding bucket. The air vents were closed during the experiments when the contrary is not stated.

The overshot chute, delivering water to the wheel on the pitch-back principle, is represented at *d*, No. 1, Fig. I, Plate IV.

To this chute three different forms of gates were applied. The first, *a*, Fig. I, Plate IV, was formed of a block three inches thick, and was opened by a motion towards the right, given by the series of levers, *l*, *l'*, *l''*, K, Plate I, (Vol. vii.) already described. The width of opening given by this gate was regulated by a series of notches upon a block, affixed to the top of the forebay, against which the end of the connecting rod, *l'*, *l''*, (Plate I,) was carried. These notches were regulated by trial. The same method of gauging the width of the opening was applied to the other apertures. When gate *a* was opened, the water flowed between its end and the top of the chute. Table A contains the results of the experiments made with this gate, under different heads.

This series of experiments being completed, the gate *b*, Fig. II, Plate IV, was adapted to the same chute; this gate drew upwards, allowing the water to pass between the lower part of the gate and the floor of the chute. Experiments similar to those, with gate *a*, were then made; the results are given in table B.

Gate *c*, Fig. III, Plate IV, was next adapted to the same chute; this gate, of a wedge form, being drawn to the right, allowed the water to pass between the tops of the gate and of the sluice. Table C contains the results obtained with this gate.

The elbow buckets remaining in the wheel, experiments were made with different heads and different widths of aperture, the water being applied at Chutes Nos. 2, 3, 4, 5, 6, and 7 successively. These points of application, taken together with Chute No. 1, embraced the cases of overshot, breast and undershot wheels. The heights of the several apertures above the lowest point of the wheel are, No. 2, 17 feet; No. 3, 13.66 feet; No. 4, 10.46 feet; No. 5, 7 feet; No. 6, 3.66 feet. No. 7 was the undershot aperture. The horizontal lines *f g*, *h i*, *k l*, *m n*, and *o p*, show the points from which these several heights above the bottom of the wheel were reckoned. The chutes through which the water was delivered from these openings, were at the entrance 16 inches by $2\frac{1}{2}$ inches, and contracted in depth (the width remaining invariable) to 2 inches, at the end where the water escaped to the wheel.

The three forms of gates (*a*, *b* and *c*) having been found nearly equally effective, either one could be applied as the convenience of opening and closing, in the position to be assumed by the gate might dictate. Fig. I, Plate IV, shows that Chutes Nos. 2, 3 and 7, were closed by gates similar to *b*, and chutes Nos. 4, 5 and 6, by gates similar to *c*. The experiments with each chute, under the various heads, will form the subject of one table.

The required results having been obtained with the elbow buck-

ets, they were removed from the wheel, and the buckets represented in sector F, C, G, (Fig. I, Plate IV,) substituted, the faces converging to the centre of the wheel. The different heads of water were then tried with each chute, and with different widths of aperture, as before. These experiments will be presented with the others in a tabular form.

Air vents, similar to those already described, were provided in the bottoms of these buckets.

The series of experiments, with the *centre buckets* having been completed, the buckets figured in sector D, C, E, (Fig. I, Plate IV,) and afterwards those in sector H, C, I, were substituted. If from any point in the periphery of the wheel, two tangents be drawn to a circle, described with the centre of the wheel as its centre, and a radius of $15\frac{1}{2}$ inches, we shall obtain the lines determining the two different buckets for that point; each bucket being equally inclined to, but on different sides of, the radius of the wheel drawn to the point, assumed, in the periphery. In sector D, C, E, the tangents to the upper side of the circle are drawn, determining the positions of the first set of *inclined buckets*. In sector H, C, I, the tangents to the lower side, giving the second set of inclined buckets.

In presenting the results of the experiments, each table will contain a single subject, and will be designated by a letter serving as a reference. To accommodate the tables to the size of the page, they will be divided into parts, designated by numbers. The general tables, as may be seen by table A, Part I, consist of 18 vertical columns, and in addition, a space for observations; each column has, at the bottom of the table, its appropriate figure of reference.

Column 1, contains the numbers by which any particular experiment may be referred to; the experiments are numbered from one upwards, through the whole extent of a table. The next three columns refer to the head of water used; column 2, containing the heights of water above the aperture; 3, the height above the top of the bucket, at which the water first strikes the wheel; and 4, the height above the bottom of the same bucket. The heads above the apertures were measured in apertures, Nos. 1, 2 and 3, by the heights above the lowest points of the tops of the gate-seats, in Nos. 4, 5 and 6, by the heights above the lowest points of the several gates when closed, and in No. 7, by the height above the bottom of the forebay, which was on a level with the bottom of the wheel. The lines *fg*, *hi*, &c. already referred to, are drawn through the points just designated, corresponding to apertures, Nos. 2, 3, 4, 5 and 6. The head, above the top of the bucket, was estimated for the overshot aperture, (No. 1,) by the height of the water above the highest point of the wheel; and that above the bottom of the bucket, by the height above the highest point of the soleing of the wheel. The heads, above the tops of the buckets, upon which the water first struck, were estimated for apertures, Nos. 2, 3, 4, 5 and 6, by the height of the water, above a point in each aperture, one-half of an inch distant from the periphery of the wheel; the horizontal lines drawn through these points are shown in Fig. I, Plate IV, by *rs*, *tu*, *vw*, *xy*, and

za'. By adding the vertical distance between the top and bottom of the bucket at any aperture, to the head, found as just described, the head, above the bottom of the bucket, was obtained. The heads thus found are contained in column 4. In a wheel considered at rest, the point corresponding to the bottom of the bucket, at which the water was delivered, would give the first point of action of the gravity of the water upon the wheel; but when the wheel is in motion, this point is generally lower down than the point which we have determined, the distance depending upon the depth of the bucket, and upon the relative velocities of the water and wheel. All the dimensions referred to, are given in feet, and decimal parts of a foot.

Column 5 contains the width of aperture; regulated by the distance to which the gate was drawn, determined in the manner already explained. The openings were increased by determinate differences, until the supply of water was more than sufficient to fill the buckets. The widths of the openings are given in inches and decimals.

The weight raised is given in column 6; this was varied with each head and aperture, until the maximum effect was reached and passed.

The friction, the method of calculating which has been given, for the machine under the particular weight raised, is contained in column 7.

Column 8, is the sum of the weights found in 6 and 7 for the different cases; the numbers represent, therefore, the total resistance overcome by the power. The weights are all given in pounds and decimals of a pound.

Column 9 contains the height through which the several weights were raised, combined with 8, it gives the effect produced.

The time occupied in each experiment is recorded in column 10, in seconds.

By dividing the distance through which the weight was raised, by the number of seconds required to raise it through that distance, the rate per second, or velocity of the weight, was determined. The velocity of the wheel will of course bear the same proportion to that of the weight, as the radius of the wheel to the sum of the radii of the barrel and chain. To avoid any uncertainty in relation to this latter quantity, the ratio was obtained experimentally, by ascertaining the number of revolutions, and parts of a revolution of the wheel, required to raise the weight through a measured distance. The velocities of the wheel are given in column 11.

The weight of water expended in each experiment, determined by measurement of its bulk in the reservoir, is contained in column 12. It was a question, whether in these experiments which would occupy a period extending through a considerable range of temperature, it was necessary to apply a correction for the temperature of the water used, the water expended being measured, not weighed. Calculation showed that no such correction was necessary.*

* The temperature of the water used, was, during the winter, about at its point of maximum density, in the summer, not far from 75° Fahr. Calling the specific gravity of water at 39.38° Fahr. its point of maximum density, unity,

Column 13 contains the head and fall, expressed in feet and decimals.

By multiplying the numbers of column 12, by the corresponding heads and falls from 13, the powers expended were obtained; the numbers expressing them are in column 14. The decimal point is omitted in this and in the succeeding column, as being unnecessary to the determination of the ratio.

Column 15 contains the numbers denoting the effect produced; these were obtained by multiplying the corresponding numbers in columns 8 and 9.

The next column, 16, gives the ratio of effect to power expended, the power being taken as unity.

The maximum effect under each head and width of aperture, is placed in column 17, that reference may be more readily made to the several maxima.

Column 18 contains the velocity of the wheel, which gave the maximum in each case.

The observations made during the progress of the experiments, are recorded in the remaining space.

Two experiments were always made under the same circumstances, when the results of these agreed it was not deemed necessary to make a third, but when they were discordant, a third, and, when required, even a fourth experiment was made to ascertain the point in doubt.

To give the two or three experiments made in each case, would be to add unnecessarily to the space which the tables must occupy: the numbers given are to be considered as so many mean results taken by those who, having been actually engaged in the course of experiment, could duly appreciate the circumstances rendering expedient the rejection of any experimental result. The tables thus become more valuable, by being rendered less voluminous and better adapted to practical use.

The tables will be followed by remarks upon them, and

the experiments of Haellstroem give for its density at 75.2° Fahr. 0.9976. If we suppose two results are to be compared, one obtained at the minimum temperature of the water, the other at the maximum, they will differ but .0024ths of the greater weight. Thus in a weight of water expended, of 10,000 lbs. the greatest difference could be but 24 lbs., or less than one division upon the gauge-plate, a number which would disappear in the ratio. Take, for example, experiment 15, Table A, which gives the highest number, contained in Part 1st, for the weight of water expended; this number is 4810 lbs.: suppose this experiment to have been made when the water was at its maximum density, and let us ascertain what effect will be produced upon the ratio, if this experiment were supposed to have been made with the water at 75.2° Fahr. The weight of water expended, occupying the same bulk with 4810 lbs. at the maximum density of water, would have been at 75.2° Fahr. 4810 × .9976, 4798.456 lbs.; this multiplied by the head and fall, 23 feet, gives for the power expended 110364.49 lbs.; the effect, (column 15,) is 91759.4, the numbers in the columns for power and effect in the table are multiplied by ten to avoid placing the decimal point. But 1103645 : 917594 : : 1 : .831, the ratio sought.

The ratio in the table, (column 16,) is .829, differing but .002 from the number just found: the effect, therefore, of neglecting the change of temperature in this extreme case falls only upon the third decimal place, the figure in which place it alters slightly.

sions drawn from them; when necessary, tables will be given presenting condensed views of particular results which are to be compared with each other.

We proceed to give the tables relating to wheel No. I.

TABLE A.—PART I.

CHUTE No. 1.—*Gate a. Pitch-back over-shot. Elbow buckets. Close breast. Water let on at upper centre of wheel.*

No. of Exper't.	Head of water above. Btm. of gate.	Top of bkt.	Btm. of bkt.	Width of Aperture.	Weight raised.	Friction.	Sum of friction and weight raised.	Height raised.	Time.	Velocity per second.	Wt of water expended.	Head and fall.	Power.	Effect.	Ratio, power being 1.	Maximum effect.	Velocity at maximum.	Observations.
	Feet.	Feet.	Feet.	In.	Pds.	Pounds.	Pounds.	Feet.	Scds.	Feet.	Pds.	Feet.						
1	2.75	3.00	3.60	0.50	257	44.54	301.54	41.5	33	11.84	835	23.0	192050	125139	.652	- -	- -	Water carried above lower centre of wheel before it was discharged from buckets.
2					416	47.32	463.32		40	9.77	1100		253000	192278	.759			
3					463	48.14	511.14		44	8.88	1200		276000	212123	.768			
4					772	53.54	825.54		69	5.66	1825		419750	342599	.816			
5					875	55.34	930.34		74	5.28	2025		465750	386091	.829	.829	5.28	Water discharged at bottom of wheel.
6					931	56.32	987.32		83	4.71	2200		506000	409738	.809			
7					978	57.14	1035.14		86	4.54	2300		529000	429583	.812			
8					1081	58.94	1139.94		94	4.16	2575		592250	473075	.799			
9	2.75	3.00	3.60	1.00	1493	73.85	1566.85	41.5	68	5.75	3450	23.0	793500	650243	.820			
10					1549	76.22	1625.22		70	5.58	3525		810750	674466	.832			
11					1596	78.22	1674.22		72	5.43	3600		828000	694801	.839	.839	5.43	
12					1699	82.59	1781.59		80	4.88	3925		902750	739360	.818			
13	2.75	3.00	3.60	1.25	1905	91.33	1996.33	41.5	66	5.92	4350	23.0	1000500	828477	.828			
14					2008	95.70	2103.70		70	5.58	4550		1046500	873035	.834	.834	5.58	
15					2111	100.07	2211.07		74	5.28	4810		1106300	917594	.829			
16	2.25	2.50	3.10	0.75	875	55.34	930.34	41.5	57	6.86	2115	22.50	475787	386091	.811			
17					1081	58.94	1139.94		69	5.66	2575		579375	473075	.815			
18					1184	60.74	1244.74		75	5.21	2800		630000	516567	.820	.820	5.21	
19					1287	65.11	1352.11		82	4.77	3050		686250	561126	.817			
20					1390	69.48	1459.48		93	4.20	3330		749250	605684	.808			
1	2	4	3	5	6	7	8	9	10	11	12	13	14	15	16	17	18	

Table A.—Part II.

Chute No. 1.—*Gate a. Pitch-back over-shot. Elbow buckets. Close breast. Water let on at upper centre of wheel.*

No. of Exper't.	Head of Water above.			Width of Aperture.	Weight raised.	Friction.	Sum of friction and weight raised.	Height raised.	Time.	Velocity per second.	Wt of water expended.	Head and fall.	Power.	Effect.	Ratio, power being 1.	Maximum effect.	Velocity at maximum.	Observations.
	Btm. of gate.	Top of bkt.	Btm. of bkt.															
	Feet.	Feet.	Feet.	In.	Pds.	Pounds	Pounds.	Feet.	Scds.	Feet.	Pds.	Feet.						
21	2.25	2.50	3.10	1.00	1184	60.74	1244.74	41.5	56	6.98	2775	22.50	624375	516567	.827			
22					1287	65.11	1352.11		60	6.51	3000		675000	561126	.831			
23					1390	69.48	1459.48		65	6.01	3225		725625	605684	.835	.835	6.01	
24					1493	73.85	1566.85		70	5.58	3500		787500	650243	.826			
25					1596	78.22	1674.22		74	5.28	3750		843750	694784	.823			
26					1699	82.59	1781.59		79	4.95	4000		900000	739360	.821			
27	2.25	2.50	3.10	1.25	1390	69.48	1459.48	41.5	51	7.66	3300	22.50	742500	605684	.816			
28					1596	78.22	1674.22		60	6.51	3750		843750	694784	.823			
29					1699	82.59	1781.59		63	6.20	3975		894375	739384	.827			
30					1802	86.96	1888.96		68	5.75	4175		939375	783918	.834			
31					1905	91.33	1996.33		71	5.50	4400		990000	828477	.837	.837	5.50	
32	1.25	1.50	2.10	0.50	669	51.74	720.74	41.5	74	5.28	1660	21.50	356900	299107	.838			
33					772	53.54	825.54		84	4.65	1900		408500	342599	.839	.839	4.65	
34					875	55.34	930.34		94	4.16	2150		462250	386091	.835			
35					978	57.14	1035.14		100	3.91	2540		546100	429583	.787			
36	1.25	1.50	2.10	0.75	875	55.34	930.34	41.5	72	5.43	2150	21.50	462250	386091	.835			
37					978	57.14	1035.14		82	4.77	2350		505250	429583	.850	.850	4.77	
38					1081	58.94	1139.94		90	4.35	2600		559000	473075	.846			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	

TABLE A.—PART III.

CHUTE No. 1.—*Gate a. Pitch-back over-shot. Elbow buckets. Close breast. Water let on at upper centre of Wheel.*

No. of Exper't.	Head of Water above. Btm. of gate.	Head of Water above. Top of Bkt.	Head of Water above. Btm. of Bkt.	Width of Aperture.	Weight raised.	Friction.	Sum of friction and weight raised.	Height raised.	Time.	Velocity per second.	W't of water expended.	Head and fall.	Power.	Effect.	Ratio, power being 1.	Maximum effect.	Velocity at maximum.	Observations.
	Feet.	Feet.	Feet.	In.	Pds.	Pounds	Pounds.	Feet.	Scds.	Feet.	Pds.	Feet.						
39	1.25	1.50	2.10	1.00	1081	58.94	1139.94	41.5	68	5.75	2600	21.50	559000	473075	.846			
40					1184	60.74	1244.74		74	5.28	2825		607375	516567	.850	.850	5.28	
41					1287	65.11	1352.11		81	4.83	3100		666500	561126	.842			
42					1390	69.48	1459.48		90	4.35	3400		731000	605684	.828			
43	1.25	1.50	2.10	1.25	1390	69.48	1459.48	41.5	70	5.58	3390	21.50	728850	605684	.831			
44					1493	73.85	1566.85		76	5.14	3650		784750	650243	.828			
45					1596	78.22	1674.22		81	4.83	3825		822375	694801	.845	.845	4.83	
46	0.50	0.75	1.35	1.25	875	55.34	930.34	41.5	62	6.30	2250	20.75	466875	386091	.828			
47					978	57.14	1035.14		67	5.83	2460		510450	429583	.842			
48					1081	58.94	1139.94		70	5.58	2675		555062	473075	.852			
49					1184	60.74	1244.74		77	5.07	2875		596562	516567	.866			
50					1287	65.11	1352.11		88	4.44	3100		643250	561126	.872	.872	4.44	
51					1390	69.48	1459.48		83	4.70	3400		705500	605684	.859			
52	0.25	0.50	1.10	0.75	360	46.34	406.34	41.5	62	6.30	1075	20.50	220375	168631	.765			
53					566	49.94	615.94		93	4.20	1550		317750	255615	.804			
54					669	51.74	720.74		98	3.99	1800		369000	299107	.810	.810	3.99	Water too low to fill the aperture.
55	0.25	0.50	1.10	1.00	772	53.54	825.54		96	4.07	2025		415125	342599	.825			
56					875	55.34	930.34		104	3.76	2275		466375	386091	.828	.828	3.76	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	

Table F.—Part II.

Chute No. 2.—*Centre buckets. Close breast. Bottom of gate seventeen feet above bottom of wheel.*

No. of Exper't.	Head of water above. Bttm. of gate.	Head of water above. Top of bkt.	Head of water above. Bttm. of bkt.	Width of Aperture.	Weight raised.	Friction.	Sum of friction and weight raised.	Height raised.	Time.	Velocity per second.	W't of water expended.	Head and fall.	Power.	Effect.	Ratio, power being 1.	Maximum effect.	Velocity at maximum.	Observations.
	Feet.	Feet.	Feet.	In.	Pds.	Pounds.	Pounds.	Feet.	Scds.	Feet.	Pds.	Feet.						
20	0.75	2.41	3.57	0.50	772	53.30	825.30	41.5	86	4.54	3525	17.75	625687	342499	.544			
21					875	55.07	930.07		86	4.54	3850		683375	385979	.564			
22					978	56.84	1034.84		88	4.44	4200		754500	429458	.576	.576	4.44	
23					1081	58.61	1139.61		111	3.52	4775		847562	472938	.555			
24	0.75	2.41	3.57	0.75	978	56.84	1034.84	41.5	71	5.50	4200	17.75	745500	429458	.576			
25					1081	58.61	1139.61		73	5.35	4425		785437	472938	.602	.602	5.35	
26					1184	60.38	1244.38		88	4.44	5025		891937	516418	.578			
27	0.75	2.41	3.57	1.00	978	56.84	1034.84	41.5	58	6.74	4025	17.75	714437	429458	.601	.609	5.75	
28					1081	58.61	1139.61		64	6.10	4420		784550	470938	.602			
29					1184	60.38	1244.38		68	5.75	4775		847562	516418	.609			
30					1287	64.74	1351.74		83	4.71	5325		945187	560972	.593			
31	0.75	2.41	3.57	1.25	978	56.84	1034.84	41.5	50	7.82	4075	17.75	723312	429458	.595			
32					1081	58.61	1139.61		58	6.74	4350		772125	472938	.611			
33					1184	60.38	1244.38		62	6.30	4750		843125	516418	.612			
34					1390	69.11	1459.11		67	5.84	5400		958500	605531	.631	.631	5.84	
35					1493	73.48	1566.48		77	5.07	6000		1065000	650089	.610			
36	0.75	2.41	3 57	1.50	1390	69.11	1459.11	41.5	45	8.70	5300	17.75	940750	605531	.643			
37					1493	73.48	1566.48		48	8.14	5700		1011750	650089	.642			
38					1596	77.85	1673.85		51	7.66	6050		1073875	694643	.646			
39					1699	82.22	1781.22		55	7.10	6450		1144875	739198	.645			
40					1802	86.59	1888.59		57	6.86	6760		1199900	783675	.653	.653	6.86	
41					1905	90.96	1295.96		63	6.20	7225		1282437	823323	.645			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	

TABLE G.—PART I.

CHUTE No. 3.—*Elbow buckets. Close breast. Bottom of gate* 13.66 *feet above bottom of wheel.*

No. of Exper't.	Head of Water above.			Width of Aperture.	Weight raised.	Friction.	Sum of friction and weight raised.	Height raised.	Time.	Velocity per second.	Wt of water expended.	Head and fall.	Power.	Effect.	Ratio, power being 1.	Maximum effect.	Velocity at maximum.	Observations.
	Btm. of gate.	Top of Bkt.	Btm. of Bkt.															
	Feet.	Feet.	Feet.	In.	Pds.	Pounds	Pounds.	Feet.	Scds.	Feet.	Pds.	Feet.						
1	9.34	11.27	12.56	0.50	463	48.05	511.05	41.5	30	13.02	2350	23.00	540500	212085	.392			
2					669	51.61	720.61		33	11.84	2820		648600	299053	.460			
3					772	53.39	825.39		35	11.16	3100		713000	342536	.480			
4					875	55.17	930.17		44	9.88	3475		799250	386020	.484			
5					978	56.95	1034.95		45	8.70	3770		867100	429504	.494	.494	8.70	
6					1081	58.73	1139.73		52	7.52	4200		966000	472987	.489			
7					1184	60.51	1244.51		56	6.98	4700		1081000	516471	.477			
8					1287	64.88	1351.88		63	6.20	5200		1196000	561030	.469			
9					1390	69.25	1459.25		63	6.20	5640		1297200	605588	.466			
10					1493	73.62	1566.62		65	6.01	6000		1380000	650146	.471			
11					1596	77.99	1673.99		69	5.66	6425		1477750	694705	.463			
2					1699	82.36	1781.36		80	4.88	7200		1656000	739263	.447			
13	9.34	11.27	12.56	0.75	772	53.39	825.39	41.5	27	14.48	3325	23.00	764750	342536	.447			
14					875	55.17	930.17		30	13.02	3525		810750	386020	.475			
15					978	56.95	1034.95		33	11.84	3850		885500	429504	.487			
16					1081	58.73	1139.73		35	11.16	4075		937250	472987	.504			
17					1184	60.51	1244.51		40	9.77	4425		1017750	516471	.507			
18					1287	64.88	1357.88		41	9.54	4780		1099400	561030	.510			
19					1390	69.25	1459.25		44	8.88	5140		1182200	605588	.512	.512	8.88	
20					1493	73.62	1566.62		47	8.32	5585		1284550	650146	.505			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	

Table G.—Part II.

Chute No. 3.—*Elbow buckets. Close breast. Bottom of gate* 13.66 *feet above bottom of wheel.*

No. of Exper't.	Head of water above. Btm. of gate.	Head of water above. Top of bkt.	Head of water above. Btm. of bkt.	Width of Aperture.	Weight raised.	Friction.	Sum of friction and weight raised.	Height raised.	Time.	Velocity per second.	Wt of water expended.	Head and fall.	Power.	Effect.	Ratio, power being 1.	Maximum effect.	Velocity at maximum.	Observations.
	Feet.	Feet.	Feet.	In.	Pds.	Pounds.	Pounds.	Feet.	Seds.	Feet.	Pds.	Feet.						
21	9.34	11.27	12.56	0.75	1596	77.99	1673.99	41.5	53	7.38	6100	23.00	1403000	694705	.495			
22					1699	82.36	1781.36		56	6.98	6575		1512250	739263	.488			
23					1802	86.73	1888.73		57	6.86	7100		1633000	783823	.485			
24					1905	91.10	1996.10		63	6.20	7520		1729600	828381	.472			
25					2008	95.47	2103.47		68	5.76	8100		1863000	872939	.467			
26					2111	99.84	2210.84		73	5.35	8625		1983750	917498	.456			
27					2214	104.21	2318.21		80	4.88	9375		2156250	962056	.446			
28	7.09	9.02	10.31	0.50	463	48.05	511.05	41.5	30	13.02	2400	20.75	498000	212085	.425			
29					566	49.83	615.83		32	12.20	2670		554025	255569	.461			
30					669	51.61	720.61		38	10.28	2910		603825	299053	.495			
31					772	53.39	825.39		43	9.09	3220		688150	342536	.509			
32					875	55.17	930.17		47	8.32	3575		741312	386020	.520	.520	8.32	
33					978	56.95	1034.95		56	6.98	4035		837262	429504	.513			
34					1081	58.73	1139.73		63	6.20	4550		944125	472987	.500			
35					1184	60.51	1244.51		67	5.84	5025		1042687	516471	.495			
36					1287	64.88	1351.88		72	5.43	5525		1156437	561030	.485			
37					1390	69.25	1459.25		80	4.88	6100		1265750	605588	.478			
38					1493	73.62	1566.62		90	4.34	6700		1390250	650146	.467			
39					1699	82.36	1781.36		103	3.79	7700		1597750	739263	.462			
40					1905	91.10	1996.10		112	3.49	8860		1838450	828381	.450			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	

Table G.—Part III.

Chute No. 3.—*Elbow buckets. Close breast. Bottom of gate* 13.66 *feet above bottom of wheel.*

No. of Experi't	Head of water above.			Width of Aperture.	Weight raised.	Friction.	Sum of friction and weight raised.	Height raised.	Time.	Velocity per second.	Wtofwater expended.	Head and fall.	Power.	Effect.	Ratio, power being 1.	Maximum effect.	Velocity at maximum.	Observations.
	Btm. of gate.	Top of bkt.	Btm. of bkt.															
	Feet.	Feet.	Feet.	In.	Pds.	Pounds	Pounds.	Feet.	Scds.	Feet.	Pds.	Feet.						
41	7.09	9.02	10.31	0.75	978	56.95	1034.95	41.5	36	10.86	3920	20.75	813400	429504	.527			
42					1081	58.73	1139.73		38	10.28	4175		866312	472987	.546			
43					1184	60.51	1244.51		41	9.53	4530		939975	516471	.549	.549	9.53	
44					1287	64.88	1351.88		46	8.50	4975		1032312	561030	.543			
45					1390	69.25	1459.25		50	7.82	5475		1136062	605588	.533			
46					1493	73.62	1566.62		53	7.37	5975		1239813	650146	.524			
47					1596	77.99	1673.99		58	6.73	6400		1328000	694705	.523			
48					1699	82.36	1781.36		60	6.51	6930		1438975	739263	.513			
49					1802	86.73	1888.73		67	5.83	7450		1545875	783823	.506			
50					1905	91.10	1996.10		74	5.28	8050		1670375	828381	.495			
51					2008	95.47	2103.47		82	4.77	8700		1805250	872939	.483			
52					2111	99.84	2210.84		86	4.54	9228		1914187	917498	.479			
53	7.09	9.02	10.31	1.00	1081	58.73	1139.73	41.5	31	12.60	4350	20.75	902625	472987	.527			
54					1184	60.51	1244.51		32	11.84	4650		964870	516471	.535			
55					1287	64.88	1351.88		36	10.86	5000		1037500	561030	.541			
56					1390	69.25	1459.25		38	10.28	5350		1110125	605588	.545			
57					1493	73.62	1566.62		40	9.77	5675		1177562	650146	.551			
58					1596	77.99	1673.99		43	9.09	6025		1250187	694705	.555	.555	9.09	
59					1699	82.36	1781.36		45	8.69	6475		1343562	739263	.550			
60					1802	86.73	1888.73		51	7.66	7000		1452500	783823	.539			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	

Table G.—Part IV.

Chute No. 3.—*Elbow buckets. Close breast. Bottom of gate* 13.66 *feet above bottom of wheel.*

No. of Expt.	Head of water above.			Width of Aperture.	Weight raised.	Friction.	Sum of friction and weight raised.	Height raised.	Time.	Velocity per second.	Wt of water expended.	Head and fall.	Power.	Effect.	Ratio, power being 1.	Maximum effect.	Velocity at maximum.	Observations.
	Btm. of gate.	Top of bkt.	Btm. of bkt.															
	Feet.	Feet.	Feet.	In.	Pds.	Pounds	Pounds.	Feet.	Scds.	Feet.	Pds.	Feet.						
61	4.09	6.02	7.31	0.50	566	49.83	615.83	41.5	40	9.77	2775	17.75	481687	255569	.530			
62					772	53.39	825.39		53	7.38	3475		616812	342536	.555	.555	7.38	
63					875	55.17	930.17		63	6.20	3975		705562	386020	.546			
64					978	56.95	1034.95		70	5.58	4460		791650	429504	.542			
65					1081	58.73	1139.73		75	5.21	4900		869750	472987	.543			
66					1184	60.51	1244.51		83	4.71	5400		958500	516471	.539			
67					1287	64.88	1351.88		100	3.91	6025		1069437	561030	.524			
68					1390	69.25	1459.25		102	3.83	6550		1162625	605588	.524			
69					1493	73.62	1566.62		109	3.59	7025		1246937	650146	.521			
70	4.09	6.02	7.31	0.75	669	51.61	720.61	41.5	37	10.56	3150	17.75	559125	299053	.534			
71					772	53.39	825.39		39	10.02	3450		612375	342536	.559			
72					875	55.17	930.17		42	9.31	3725		661187	386020	.584			
73					978	56.95	1034.95		45	8.70	4075		723312	429504	.593			
74					1081	58.73	1139.73		51	7.66	4450		789875	472987	.598			
75					1184	60.51	1244.51		51	7.66	4800		852000	516471	.606	.606	7.66	
76					1287	64.88	1351.88		62	6.30	5350		949625	561030	.590			
77					1390	69.25	1459.25		65	6.00	5800		1029500	605588	.588			
78					1493	73.62	1566.62		73	5.35	6400		1136000	650146	.574			
79					1596	77.99	1673.99		77	5.07	6950		1233625	694705	.562			
80					1699	82.36	1781.36		83	4.71	7500		1331250	739263	.555			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	

Table G.—Part V.

Chute No. 3.—*Elbow buckets. Close breast. Bottom of gate* 13.66 *feet above bottom of wheel.*

No. of Exper't.	Head of water above.			Width of Aperture.	Weight raised.	Friction.	Sum of friction and weight raised.	Height raised.	Time.	Velocity per second.	Wt of water expended.	Head and fall.	Power.	Effect.	Ratio, power being 1.	Maximum effect.	Velocity at maximum.	Observations.
	B of e. gat	Top of bkt.	Btm. of bkt.															
	Feet.	Feet.	Feet.	In.	Pds.	Pounds	Pounds.	Feet.	Scds.	Feet.	Pds.	Feet.						
81	4.09	6.02	7.31	1.00	875	55.17	930.17	41.5	36	10.86	3800	17.75	674500	386020	.572			
82					978	56.95	1034.95		38	10.28	4125		732187	429504	.586			
83					1081	58.73	1139.73		42	9.31	4500		798750	472987	.591			
84					1184	60.51	1244.51		43	9.09	4825		856437	516471	.603			
85					1287	64.88	1351.88		47	8.32	5225		927437	561030	.605	.605	8.32	
86					1390	69.25	1459.25		52	7.52	5700		1011750	605588	.598			
87					1493	73.62	1566.62		57	6.85	6225		1104937	650147	.588			
88					1596	77.99	1673.99		60	6.50	6650		1180375	694705	.588			
89					1802	86.73	1888.73		71	5.50	7725		1371187	783822	.571			
90					2008	95.47	2103.47		82	4.77	8900		1579750	872939	.552			
91	1.09	3.02	4.31	0.75	566	49.83	615.83	41.5	49	7.98	2850	14.75	420375	255569	.608			
92					669	51.61	720.61		62	6.30	3250		479375	299053	.624			
93					772	53.39	825.39		64	6.10	3650		538375	342536	.636	.636	6.10	
94					875	55.17	930.17		73	5.35	4150		612125	386020	.630			
95					978	56.95	1034.95		81	4.83	4650		685875	429504	.626			
96					1081	58.73	1139.73		87	4.49	5175		763312	472987	.619			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	

Table G.—Part VI.

Chute No. 3.—*Elbow buckets. Close breast. Bottom of gate* 13.66 *feet above bottom of wheel.*

No. of Exper't.	Head of water above.			Width of Aperture.	Weight raised.	Friction.	Sum of friction and weight raised.	Height raised.	Time.	Velocity per second.	Wt of water expended.	Head and fall.	Power.	Effect.	Ratio, power being 1.	Maximum effect.	Velocity at maximum.	Observations.
	Btm. of gate.	Top of bkt.	Btm. of bkt.															
	Feet.	Feet.	Feet.	In.	Pds.	Pounds	Pounds.	Feet.	Scds.	Feet.	Pds.	Feet.						
97	1.09	3.02	4.31	1.00	772	53.39	825.39	41.5	51	7.66	3675	14.75	542062	342536	.631			
98					875	55.17	930.17		61	6.40	4100		604750	386020	.638			
99					978	56.95	1034.95		62	6.30	4500		663750	429504	.647	.647	6.30	
100					1081	58.73	1139.73		70	5.58	5000		737500	472987	.641			
101					1184	60.51	1244.51		81	4.83	5500		811250	516471	.636			
102					1287	64.88	1351.88		88	4.44	6000		885000	561030	.633			
103					1390	69.25	1459.25		90	4.35	6500		958750	605588	.631			
104	1.09	3.02	4.31	1.25	1081	58.73	1139.73	41.5	60	6.50	4900	14.75	722750	472987	.654			
105					1184	60.51	1244.51		63	6.20	5325		785437	516471	.657			
106					1287	64 88	1351.88		69	5.66	5775		851812	561030	.658	.658	5.66	
107					1390	69.25	1459.25		74	5.28	6325		932937	605588	.649			
108					1493	73.62	1566.62		82	4.77	6875		1014062	650147	.641			
109					1596	77.99	1673.99		90	4.35	7375		1087812	694705	.641			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	

Table H.—Part I.

Chute No. 3.—*Centre buckets. Close breast. Bottom of gate* 13.66 *feet above bottom of wheel.*

No. of Exper't.	Head of water above. Btm. of gate.	Head of water above. Top of bkt.	Head of water above. Btm. of bkt.	Width of Aperture.	Weight raised.	Friction.	Sum of friction and weight raised.	Height raised.	Time.	Velocity per second.	W't of water expended.	Head and fall.	Power.	Effect.	Ratio, power being 1.	Maximum effect.	Velocity at maximum.	Observations.
	Feet.	Feet.	Feet.	In.	Pds.	Pounds	Pounds.	Feet.	Scds.	Feet.	Pds.	Feet.						
1	9.34	11.27	12.56	0.50	669	51.61	720.61	41.5	39	10.02	3000	23.00	690000	299053	.433			
2					772	53.39	825.39		42	9.31	3275		753250	342536	.454			
3					875	55.17	930.17		46	8.50	3625		833750	386020	.462	.462	8.50	
4					978	56.95	1034.95		49	7.98	4085		939550	429504	.457			
5	9.34	11.27	12.56	0.75	669	51.61	720.61	41.5	27	14.48	3200	23.00	736000	299053	.406			
6					875	55.17	930.17		34	11.50	3625		833750	386020	.462			
7					1081	58.73	1139.73		36	10.86	4250		977500	472987	.484	.484	10.86	
8					1184	60.51	1244.51		41	9.54	4650		1069500	516471	.483			
9					1287	64.88	1351.88		45	8.71	5075		1167250	561030	.480			
10					1390	69.25	1459.25		50	7.82	5600		1288000	605588	.470			
11					1493	73.62	1566.62		60	6.50	6235		1434050	650146	.453			
12	9 34	11.27	12.56	1.00	1493	73.62	1566.62	41.5	40	9.77	5575	23.00	1282250	650147	.507	.507	9.77	
13					1596	77.99	1673.99		42	9.31	6050		1391500	694705	.499			
14	7.09	9.02	10.31	0.50	566	49.83	615.83	41.5	40	9.77	2800	20.75	581000	255569	.436			
15					669	51.61	720.61		43	9.09	3125		648437	299053	.451			
16					772	53.39	825.39		48	8.14	3475		721062	342536	.475	.475	8.14	
17					875	55.17	930.17		56	6.98	3930		815475	386020	.472			
18					978	56.95	1034.95		61	6.40	4400		913000	429504	.470			
19					1081	58.73	1139.73		69	6.66	4900		1016750	472987	.465			
20					1184	60.51	1244.51		75	5.21	5535		1148512	516471	.449			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	

TABLE H.—PART II.

CHUTE NO. 3.—*Centre buckets. Close breast. Bottom of gate* 13.66 *feet above bottom of wheel.*

No. of Exper't.	Head of water above. Btm. of gate.	Top of bkt.	Btm. of bkt.	Width of Aperture.	Weight raised.	Friction.	Sum of friction and weight raised.	Height raised.	Time.	Velocity per second.	Wt of water expended.	Head and fall.	Power.	Effect.	Ratio, power being 1.	Maximum effect.	Velocity at maximum.	Observations.
	Feet.	Feet.	Feet.	In.	Pds.	Pounds	Pounds.	Feet.	Scds.	Feet.	Pds.	Feet.						
21	7.09	9.02	10.31	0.75	875	55.17	930.17	41.5	36	10.86	3800	20.75	788500	386020	.489			
22					978	56.95	1034.95		38	10.28	4110		852825	429504	.503			
23					1081	58.73	1139.73		43	9.09	4500		933750	472987	.506	.506	9.09	
24					1184	60.51	1244.51		51	7.66	4975		1032312	516471	.500			
25					1287	64.88	1351.88		63	6.20	5725		1187937	561030	.472			
26	7.09	9.02	10.31	1.00	1081	58.73	1139.73	41.5	35	11.16	4435	20.75	920262	472987	.514			
27					1184	60.51	1244.51		39	10.02	4800		996000	516471	.518			
28					1287	64.88	1351.88		43	9.09	5225		1084187	561030	.517			
29					1390	69.25	1459.25		46	8.50	5575		1156812	605588	.523	.523	8.50	
30					1493	73.62	1566.62		50	7.82	6225		1291687	650147	.503			
31					1596	77.99	1673.99		56	6.98	6725		1395437	694705	.498			
32	4.09	6.02	7.31	0.75	978	56.95	1034.95	41.5	50	7.82	4425	17.75	785437	429504	.547	.547	7.98	
33					1081	58.73	1139.73		54	7.23	4895		868862	472987	.542			
34					1184	60.51	1244.51		66	5.92	5475		971812	516471	.531			
35					1287	64.88	1351.88		73	5.35	6125		1087187	561030	.516			
36					1390	69.25	1459.25		78	5.01	6675		1184812	605588	511			
37	4.09	6.02	7.31	1.00	1081	58.73	1139.73	41.5	45	8.69	4710	17.75	836025	472987	.561			
38					1184	60.51	1244.51		50	7.82	5125		909687	516471	.567	.567	7.98	
39					1287	64.88	1351.88		52	7.51	5600		994000	561030	.564			
1	2	3	4	5	6	7	8	9	10	11	91	13	14	15	16	17	18	

TABLE H.—PART III.

CHUTE No. 3.—*Centre buckets. Close breast. Bottom of gate* 13.66 *feet above bottom of wheel.*

No. of Exper't.	Head of Water above.			Width of Aperture.	Weight raised.	Friction.	Sum of friction and weight raised.	Height raised.	Time.	Velocity per second.	Wt of water expended.	Head and fall.	Power.	Effect.	Ratio, power being 1.	Maximum effect.	Velocity at maximum.	Observations.
	Btm. of gate.	Top of bkt.	Btm. of bkt.															
	Feet.	Feet.	Feet.	In.	Pds.	Pounds	Pounds.	Feet.	Scds.	Feet.	Pds.	Feet.						
40	1.09	3.02	4.31	1.00	669	51.61	720.61	41.5	54	7.23	3600	14.75	531000	299053	.563			
41					772	53.39	825.39		63	6.20	4025		593687	342536	.576			
42					875	55.17	930.17		69	5.66	4450		656375	386020	.588	.588	5.66	
43					978	56.95	1034.95		77	5.07	4950		730125	429504	.588			
44					1081	58.73	1139.73		88	4.44	5500		811250	472987	.583			
45					1184	60.51	1244.51		92	4.24	6025		888678	516471	.581			
46	1.09	3.02	4.31	1.25	978	56.95	1034.95	41.5	44	8.88	4975	14.75	733812	429504	.585			
47					1081	58.73	1139.73		49	7.98	5435		801662	472987	.589			
48					1184	60.51	1244.51		52	7.51	5835		860662	516471	.600			
49					1287	64.88	1351.88		56	6.98	6275		925562	561030	.606			
50					1390	69.25	1459.25		62	6.30	6750		995625	605588	.607			
51					1493	73.62	1566.62		66	5.92	7250		1069375	650147	.608			
52					1596	77.99	1673.99		68	5.75	7625		1124687	694705	.617	.617	5.75	
53					1699	82.36	1781.36		71	5.50	8125		1198437	739263	.616			
54					1802	86.73	1888.73		80	4.88	8750		1290625	783822	.607			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	

Table H.—Part IV.

Chute No. 3.—*Centre buckets. Close breast. Bottom of gate* 13.66 *feet above bottom of wheel.*

No. of Exper't.	Head of water above. Btm of gate	Top of bkt.	Btm. of bkt.	Width of Aperture.	Weight raised.	Friction.	Sum of friction and weight raised.	Height raised.	Time.	Velocity per second.	Wt of water expended.	Head and fall.	Power.	Effect.	Ratio, power being 1.	Maximum effect.	Velocity at maximum.	Observations.
	Feet.	Feet.	Feet.	In.	Pds.	Pounds	Pounds.	Feet.	Scds.	Feet.	Pds.	Feet.						
55	1.09	3.02	4.31	1.50	1596	77.99	1673.99	41.5	64	6.10	7600	14.75	1121000	694705	.619			
56					1699	82.36	1781.36		66	5.9 9	8050		1187375	739263	.624			
57					1802	86.73	1888.73		69	5.66	8475		1250062	783822	.627	.627	5.66	
58					1905	91.10	1996.10		74	5.98	9025		1331187	828381	.622			
59					2008	95.47	2103.47		79	4.95	9725		1434437	872939	.608			
60	1.09	3.02	4.31	1.75	1699	82.36	1781.36	41.5	59	6.6	8030	14.75	1184425	739263	.624			
61					1802	86.73	1888.73		64	6.10	8460		1247850	783822	.628	.628	6.10	
62					1905	91.10	1996.10		67	5.83	9000		1327500	828381	.624			
63					2008	95.47	2103.47		7	5.43	9600		1416000	872939	.616			
64					2111	99.84	2210.84		77	5.07	10330		1523675	917498	.602			
65	4.09	6.02	7.31	1.00	1184	60.51	1244.51	41.5	44	8.88	4925	17.75	874187	516471	.590			Air vents open.
66					1287	44.88	1351.88		47	8.31	5300		940750	561030	.596			
67					1390	69.25	1459.25		51	7.66	5700		1011750	605588	.598	.598	7.66	
68					1493	73.62	1566.62		56	6.98	6160		1093400	650147	.594			
69					1596	77.99	1673.99		61	6.40	6625		1175937	694705	.590			
70					1802	86.73	1888.73		69	5.66	7650		1357875	783822	.577			
71					2008	95.47	2103.47		90	4.34	8650		1535375	872939	.568			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	

Table I.—Part I.

Chute No. 4.—*Elbow buckets. Close breast. Bottom of gate* 10.46 *feet above bottom of wheel.*

No. of Exper't.	Head of water above.			Width of Aperture.	Weight raised.	Friction.	Sum of friction and weight raised.	Height raised.	Time.	Velocity per second.	Wt of water expended.	Head and fall.	Power.	Effect.	Ratio, power being 1.	Maximum effect.	Velocity at maximum.	Observations.
	Btm. of gate.	Top of bkt.	Btm. of bkt.															
	Feet.	Feet.	Feet.	In.	Pds.	Pounds.	Pounds.	Feet.	Scds.	Feet.	Pds.	Feet.						
1	12.54	14.47	15.72	0.50	566	50.00	616.00	41.5	38	10.28	2850	23.00	655500	255640	.389			
2					669	51.81	720.81		44	8.88	3275		753250	299136	.397	.397	8.88	
3					772	53.62	825.62		50	7.82	3800		874000	342632	.392			
4					875	55.43	930.43		59	6.62	4400		1012000	386128	.381			
5					978	57.24	1035.24		69	5.66	5110		1175300	429624	.365			
6					1081	59.05	1140.05		79	4.95	5825		1339750	473120	.353			
7	12.54	14.47	15.72	0.75	566	50.00	616.00	41.5	26	15.03	3050	23.00	701500	255640	.364			
8					669	51.81	720.81		27	14.48	3400		782000	299136	.382			
9					772	53.62	825.62		30	13.02	3650		839500	342632	.408			
10					875	55.43	930.43		34	11.50	3970		913100	386128	.422			
11					978	57.24	1035.24		37	10.56	4350		1000500	429624	.429	.429	10.56	
12					1081	59.05	1140.05		41	9.54	4825		1109750	473120	.426			
13					1184	60.86	1244.86		44	8.88	5275		1213250	516617	.425			
14					1287	65.23	1352.23		49	7.98	5875		1351250	561175	.417			
15					1390	69.60	1459.60		55	7.10	6500		1495000	605734	.415			
16					1493	73.97	1566.97		60	6.50	7250		1667500	650293	.390			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	

Table I.—Part II.

Chute No. 4.—*Elbow buckets. Close breast. Bottom of gate* 10.46 *feet above bottom of wheel.*

No. of Exper't.	Head of water above.			Width of Aperture.	Weight raised.	Friction.	Sum of friction and weight raised.	Height raised.	Time.	Velocity per second.	Wt of water expended.	Head and fall.	Power.	Effect.	Ratio, power being 1.	Maximum effect.	Velocity at maximum.	Observations.
	Btm. of gate.	Top of bkt.	Btm. of bkt.															
	Feet.	Feet.	Feet.	In.	Pds.	Pounds	Pounds.	Feet.	Scds.	Feet.	Pds.	Feet.						
17	10.29	12.22	13.47	0.75	669	51.81	720.81	41.5	32	12.20	3475	20.75	721062	299136	.414			
18					772	53.62	825.62		33	11.84	3800		788500	342632	.434			
19					875	55.43	930.43		38	10.28	4175		866312	386128	.445			
20					978	57.24	1035.24		41	9.53	4600		954500	429624	.450	.450	9.53	
21					1081	59.05	1140.05		46	8.50	5125		1063437	473120	.445			
22					1184	60.86	1244.86		51	7.66	5700		1182750	516617	.435			
23					1287	65.23	1352.23		57	6.86	6300		1307250	561175	.428			
24					1390	69.60	1459.60		64	6.10	7050		1462875	605734	.414			
25	10.29	12.22	13.47	1.00	875	55.43	930.43	41.5	29	13.48	4425	20.75	918187	386128	.420			
26					1081	59.05	1140.05		35	11.16	5050		1047875	473120	.451	.451	11.16	
27					1184	60.86	1244.86		38	10.28	5585		1158887	516617	.445			
28					1287	65.23	1352.23		40	9.77	6100		1265850	561175	.443			
29					1390	69.60	1459.60		45	8.71	6675		1385062	605734	.437			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	

TABLE I.—PART III.

CHUTE NO. 4.—*Elbow buckets. Close breast. Bottom of gate* 10.46 *feet above bottom of wheel.*

No. of Exper't.	Head of water above. Btm. of gate.	Top of bkt.	Btm. of bkt.	Width of Aperture.	Weight raised.	Friction.	Sum of friction and weight raised.	Height raised.	Time.	Velocity per second.	Wt of water expended.	Head and fall.	Power.	Effect.	Ratio, power being 1.	Maximum effect.	Velocity at maximum.	Observations.
	Feet.	Feet.	Feet.	In.	Pds.	Pounds	Pounds.	Feet.	Scds.	Feet.	Pds.	Feet.						
30	7.29	9.22	10.47	0.75	566	50.00	616.00	41.5	33	11.84	3300	17.75	585750	255640	.436			
31					669	51.81	720.81		38	10.28	3625		643437	299136	.465			
32					772	53.62	825.62		41	9.54	4075		723312	342632	.473			
33					875	55.43	930.43		47	8.32	4550		807625	386128	.478	.478	8.32	
34					978	57.24	1035.24		53	7.38	5125		909687	429624	.472			
35					1081	59.05	1140.05		58	6.74	5700		1011750	473120	.467			
36					1184	60.86	1244.86		65	6.00	6375		1131562	516617	.456			
37					1287	65.23	1352.23		73	5.35	7125		1264687	561175	.443			
38	7.29	9.22	10.47	1.00	978	57.24	1035.24	41.5	39	10.02	4925	17.75	874187	429624	.491			
39					1081	59.05	1140.05		43	9.09	5400		958500	473120	.493	.493	9.09	
40					1184	60.86	1244.86		46	8.50	6000		1065000	516617	.485			
41					1287	65.23	1352.23		52	7.52	6575		1167062	561175	.480			
42					1390	69.60	1459.60		58	6.74	7225		1282437	605734	.473			
43					1493	73.97	1566.97		63	6.20	7850		1393375	650293	.466			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	

Table I.—Part IV.

Chute No. 4.—*Elbow buckets. Close breast. Bottom of gate* 10.46 *feet above bottom of wheel.*

No. of Exper't.	Head of water above.			Width of Aperture.	Weight raised.	Friction.	Sum of friction and weight raised.	Height raised.	Time.	Velocity per second.	W't of water expended.	Head and fall.	Power.	Effect.	Ratio, power being 1.	Maximum effect.	Velocity at maximum.	Observations.
	Btm. of gate.	Top of bkt.	Btm. of bkt.															
	Feet.	Feet.	Feet.	In.	Pds.	Pounds	Pounds.	Feet.	Scds.	Feet.	Pds.	Feet.						
44	4.29	6.22	7.47	0.75	463	48.19	511.19	41.5	38	10.28	3010	14.75	443975	212144	.477			Experiments were made on a head of 11.75 feet, but the back of the chute was too high to permit a flow sufficient to fill the aperture; in consequence of this, the ratios did not increase in a due proportion to the diminution of the head. It has not been deemed necessary to record those experiments in the tables.
45					566	50.00	616.00		45	8.71	3475		512562	255640	.498			
46					669	51.81	720.81		50	7.82	3975		586312	299136	.510			
47					772	53.62	825.62		57	6.86	4525		667437	342632	.513	.513	6.86	
48					875	55.43	930.43		66	5.92	5150		759625	386128	.508			
49					978	57.24	1035.24		75	5.21	5875		866562	429624	.495			
50					1081	59.05	1140.05		85	4.60	6650		980875	473120	.482			
51	4.29	6.22	7.47	1.00	772	53.62	825.62	41.5	43	9.09	4350	14.75	641625	342632	.534			
52					875	55.43	930.43		48	8.14	4860		716850	386128	.538	.538	8.14	
53					978	57.24	1035.24		55	7.10	5450		803870	429624	.534			
54					1081	59.05	1140.05		59	6.62	6075		896062	473120	.528			
55	4.29	6.22	7.47	1.25	875	55.43	930.43	41.5	40	9.77	4850	14.75	718370	386128	.537			
56					978	57.24	1035.24		44	8.88	5350		789120	429624	.544	.544	8.88	
57					1081	59.05	1140.05		49	7.98	5925		873937	473120	.541			
58					1184	60.86	1244.86		54	7.24	6575		969812	516617	.532			
59					1287	65.23	1352.23		61	6.40	7225		1065687	561175	.526			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	

Table K.—Part I.

Chute No. 4.—*Centre buckets. Bottom of gate* 10.46 *feet above bottom of wheel.*

No. of Expr't.	Head of water above.			Width of Aperture.	Weight raised.	Friction.	Sum of friction and weight raised.	Height raised.	Time.	Velocity per second.	Wt of water expended.	Head and fall.	Power.	Effect.	Ratio, power being 1.	Maximum effect.	Velocity at maximum.	Observations.
	Btm. of gate.	Top of bkt.	Btm. of bkt.															
	Feet.	Feet.	Feet.	In.	Pds.	Pounds	Pounds.	Feet.	Scds.	Feet.	Pds.	Feet.						
1	12.54	14.47	15.72	0.50	360	46.38	406.38	41.5	38	10.28	2210	23.00	508300	168647	.331			
2					463	48.19	511.19		47	8.32	2650		609500	212144	.348			
3					566	50.00	616.00		55	7.10	3135		721050	255640	.354	.354	7.10	
4					669	51.81	720.81		66	5.92	3710		853300	299136	.350			
5	12.54	14.47	15.72	0.75	669	51.81	720.81	41.5	33	11.84	3420	23.00	786600	299136	.380			
6					772	53.62	825.62		38	10.28	3800		874000	342632	.393			
7					875	55.43	930.43		40	9.77	4155		955650	386128	.404			
8					978	57.24	1035.24		43	9.09	4560		1048800	429624	.409	.409	9.09	
9					1081	59.05	1140.05		46	8.50	5050		1161500	473120	.407			
10					1184	60.86	1244.86		48	8.14	5525		1270750	516617	.406			
11					1287	65.23	1352.23		53	7.38	6125		1408750	561175	.398			
12	12.54	14.47	15.72	1.00	772	53.62	825.62	41.5	29	13.48	3910	23.00	893730	342632	.383			
13					875	55.43	930.43		32	12.20	4160		956800	386128	.403			
14					978	57.24	1035.24		36	10.86	4560		1048800	429624	.409			
15					1081	59.05	1140.05		39	10.02	4990		1147700	473120	.412			
16					1184	60.86	1244.86		40	9.77	5375		1236250	516617	.418	.418	9.77	
17					1287	65.23	1352.23		43	9.09	5850		1345500	561175	.417			
18					1390	69.60	1459.60		46	8.50	6375		1466250	605734	.413			
19					1493	73.97	1566.97		53	7.38	7105		1634150	650293	.398			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	

Table K.—Part II.

Chute No. 4.—*Centre buckets. Bottom of gate* 10.46 *feet above bottom of wheel.*

No. of Exper't.	Head of Water above. Btm. of gate. Feet.	Head of Water above. Btm. of Bkt. Feet.	Head of Water above. Top of Bkt. Feet.	Width of Aperture. In.	Weight raised. Pds.	Friction. Pounds	Sum of friction and weight raised. Pounds.	Height raised. Feet.	Time. Seds.	Velocity per second. Feet.	Wt of water expended. Pds.	Head and fall. Feet.	Power.	Effect.	Ratio, power being 1.	Maximum effect.	Velocity at maximum.	Observations.
20	10.29	12.22	13.47	0.50	360	46.38	406.38	41.5	39	10.02	2370	20.75	491775	168647	.343			
21					463	48.19	511.19		47	8.32	2830		587225	212144	.361			
22					566	50.00	616.00		50	7.82	3250		674375	255640	.379	.379	7.82	
23					669	51.81	720.81		67	5.84	3950		819625	299136	.364			
24	10.29	12.22	13.47	0.75	669	51.81	720.81	41.5	35	11.16	3635	20.75	754262	299136	.396			
25					772	53.62	825.62		39	10.02	4000		830000	342632	.413			
26					875	55.43	930.43		41	9.54	4430		919225	386128	.420			
27					978	57.24	1035.24		47	8.32	4910		1018825	429624	.421	.421	8.32	
28					1081	59.05	1140.05		54	7.24	5470		1135025	473120	.416			
29					1184	60.86	1244.86		59	6.62	6065		1258487	516617	.410			
30	10.29	12.22	13.47	1.00	978	57.24	1035.24	41.5	38	10.28	4780	20.75	991850	429624	.433			
31					1081	59.05	1140.05		40	9.77	5200		1079000	473120	.438			
32					1184	60.86	1244.86		44	8.88	5645		1171337	516617	.441	.441	8.88	
33					1287	65.23	1352.23		48	8.14	6275		1302062	561175	.431			
34					1390	69.60	1459.60		54	7.24	6900		1431750	605734	.423			
35	10.29	12.22	13.47	1.25	1081	59.05	1140.05	41.5	32	12.20	5150	20.75	1068625	473120	.442			
36					1184	60.86	1244.86		35	11.16	5580		1157850	516617	.446			
37					1287	65.23	1352.23		37	10.56	5880		1220100	561175	.460	.460	10.56	
38					1390	69.60	1459.60		41	9.54	6450		1338375	605734	.452			
39					1493	73.97	1566.97		44	8.88	7000		1452500	650293	.447			
1	2	4	3	5	6	7	8	9	10	11	12	13	14	15	16	17	18	

Table K.—Part III.

Chute No. 4.—*Centre buckets. Bottom of gate* 10.46 *feet above bottom of wheel.*

No. of Exper't.	Head of water above.			Width of Aperture.	Weight raised.	Friction.	Sum of friction and weight raised.	Height raised.	Time.	Velocity per second.	Wt of water expended.	Head and fall.	Power.	Effect.	Ratio, power being 1.	Maximum effect.	Velocity at maximum.	Observations.
	Btm. of gate.	Top of bkt.	Btm. of bkt.															
	Feet.	Feet.	Feet.	In.	Pds.	Pounds	Pounds.	Feet.	Scds.	Feet.	Pds.	Feet.						
40	7.29	9.22	10.47	0.50	257	44.57	301.57	41.5	37	10.56	2050	17.75	363875	125152	.344			
41					360	46.38	406.38		45	8.70	2520		447300	168647	.377			
42					463	48.19	511.19		53	7.38	3010		534275	212144	.397			
43					566	50.00	616.00		64	6.10	3575		634562	255640	.403			
44					669	51.81	720.81		73	5.35	4160		738400	299136	.405	.405	5.35	
45					772	53.62	825.62		86	4.54	4875		865312	342632	.396			
46					875	55.43	930.43		105	3.72	5700		1011750	386128	.381			
47	7.29	9.22	10.47	0.75	669	51.81	720.81	41.5	42	9.31	3835	17.75	680712	299136	.439			
48					772	53.62	825.62		46	8.50	4240		752600	342632	.455	.455	8.50	
49					875	55.43	930.43		52	7.52	4790		850225	386128	.454			
50					978	57.24	1035.24		58	6.74	5350		949625	429624	.452			
51	7.29	9.22	10.47	1.00	875	55.43	930.43	41.5	42	9.31	4675	17.75	829812	386128	.465			
52					978	57.24	1035.24		46	8.50	5110		907250	429624	.473	.473	8.50	
53					1081	59.05	1140.05		50	7.82	5650		1002875	473120	.471			
54					1184	60.86	1244.86		54	7.24	6225		1104937	516617	.467			
55					1287	65.23	1352.23		62	6.30	6935		1230962	560175	.455			
56	7.29	9.22	10.47	1.25	978	57.24	1035.24	41.5	37	10.56	5120	17.75	908800	429624	.472			
57					1081	59.05	1140.05		39	10.02	5500		976250	473120	.484			
58					1184	60.86	1244.86		44	8.88	6000		1065000	516617	.485	.485	8.88	
59					1287	65.23	1352.23		47	8.32	6530		1159075	560175	.483			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	

Table K.—Part IV.

Chute No. 4.—*Centre buckets. Bottom of gate* 10.46 *feet above bottom of wheel.*

No. of Exper't.	Head of water above. Btm. of gate.	Head of water above. Top of bkt.	Head of water above. Btm. of bkt.	Width of Aperture.	Weight raised.	Friction.	Sum of friction and weight raised.	Height raised.	Time.	Velocity per second.	W't of water expended.	Head and fall.	Power.	Effect.	Ratio, power being 1.	Maximum effect.	Velocity at maximum.	Observations.
	Feet.	Feet.	Feet.	In.	Pds.	Pounds	Pounds.	Feet.	Scds.	Feet.	Pds.	Feet.						
60	7.29	9.22	10.47	1.50	1081	59.05	1140.05	41.5	34	11.50	5550	17.75	985125	473120	.480			
61					1184	60.86	1244.86		38	10.28	5950		1056125	516617	.489			
62					1287	65.23	1352.23		40	9.77	6400		1136000	561175	.494			
63					1390	69.60	1459.60		43	9.09	6850		1215875	605734	.498	.498	9.09	
64					1493	73.97	1566.97		46	8.50	7500		1331250	650293	.488			
65					1596	78.34	1674.34		50	7.82	8110		1439525	694851	.482			
66	4.29	6.22	7.47	0.75	463	48.19	511.19	41.5	47	8.32	3175	14.75	468312	212144	.453			
67					566	50.00	616.00		57	6.86	3725		549437	255640	.465			
68					669	51.81	720.81		66	5.92	4270		629825	299136	.474	.474	5.92	
69					772	53.62	825.62		76	5.14	4975		733812	342632	.466			
70	4.29	6.22	7.47	1.00	566	50.00	616.00	41.5	40	9.77	3700	14.75	545750	255640	.468			
71					669	51.81	720.81		46	8.50	4150		612125	299136	.488			
72					772	53.62	825.62		52	7.52	4635		683662	342632	.500			
73					875	55.43	930.43		58	6.74	5160		761100	386128	.507	.507	6.74	
74					978	57.24	1035.24		64	6.10	5750		848125	429624	.506			
75					1081	59.05	1140.05		71	5.50	6410		945475	473120	.500			
76	4.29	9.22	7.47	1.25	875	55.43	940.43	41.5	46	8.50	5000	14.75	737500	386128	.523			
77					978	57.24	1035.24		50	7.82	5500		811250	429624	.529	.529	7.82	
78					1081	59.05	1140.05		56	6.98	6100		899750	473120	.525			
79					1184	60.86	1244.86		61	6.40	6700		988250	516617	.522			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	

Table K.—Part V.

Chute No. 4.—*Centre buckets. Bottom of gate* 10.46 *feet above bottom of wheel.*

No. of Exper't.	Head of water above.			Width of Aperture	Weight raised.	Friction.	Sum of friction and weight raised.	Height raised.	Time.	Velocity per second.	W't of water expended.	Head and fall.	Power.	Effect.	Ratio, power being 1.	Maximum effect.	Velocity at maximum.	Observations.
	Btm. of gate.	Top of bkt.	Btm. of bkt.															
	Feet.	Feet.	Feet.	In.	Pds.	Pds.	Pounds.	Feet.	Scds.	Feet.	Pds.	Feet.						
80	4.29	6.22	7.47	1.50	978	57.24	135.24	41.5	43	9.09	5470	14.75	806825	429624	.532			
81					1081	59.05	1140.05		46	8.50	5875		866562	473120	.546	.546	8.50	
82					1184	60.86	1244.86		51	7.66	6525		962437	516617	.536			
83					1287	65.23	1352.23		56	6.98	7135		1052412	561175	.533			
84	4.29	6.22	7.47	1.75	1081	59.05	1140.05	41.5	35	11.16	6325	14.75	932937	473120	.507			
85					1184	60.86	1244.86		37	10.56	6765		997837	516617	.517			
86					1287	65.23	1352.23		39	10.02	7125		1050931	561175	.534			
87					1390	69.60	1459.60		43	9.09	7625		1124687	605734	.538			
88					1493	73.97	1566.97		44	8.88	8050		1187375	650293	.547	.547	8.88	
89					1596	78.34	1674.34		56	6.98	8875		1309062	694851	.530			
90	1.54	3.47	4.72	1.00	257	44.57	301.57	41.5	41	9.54	2350	12.00	282000	125152	.443			
91					463	48.19	511.19		60	6.50	3400		408000	212144	.520			
92					566	50.00	616.00		70	5.58	4010		481200	255640	.531			
93					669	51.81	720.81		82	4.77	4650		558000	299136	.536	.536	4.77	
94					772	53.62	825.62		95	4.11	5400		648000	342632	.528			
95					875	55.43	930.43		110	3.55	6225		747000	386128	.517			
96	1.54	3.47	4.72	1.25	566	50.00	616.00	41.5	57	6.86	3910	12.00	469200	255640	.544			
97					669	51.81	720.81		67	5.84	4475		537000	299136	.556			
98					772	53.62	825.62		74	5.28	5100		612000	342632	.559	.559	5.28	
99					875	55.43	930.43		86	4.54	5935		712200	386128	.542			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	

Table K.—Part VI.

Chute No. 4.—*Centre buckets. Bottom of gate* 10.46 *feet above bottom of wheel.*

No. of Expt.	Head of water above.			Width of Aperture.	Weight raised.	Friction.	Sum of friction and weight raised.	Height raised.	Time.	Velocity per second.	W't of water expended.	Head and fall.	Power.	Effect.	Ratio, power being 1.	Maximum effect.	Velocity at maximum.	Observations.
	Btm. of gate.	Top of bkt.	Btm. of bkt.															
	Feet.	Feet.	Feet.	In.	Pds.	Pds.	Pounds.	Feet.	Scds.	Feet.	Pds.	Feet.						
100	1.54	3.47	4.72	1.50	566	50.00	616.00	41.5	49	7.98	3885	12.00	466200	255640	.548			
101					669	51.81	720.81		59	6.62	4475		537000	299136	.557			
102					772	53.62	825.62		66	5.92	5050		606000	342632	.565			
103					875	55.43	930.43		73	5.35	5680		681600	386128	.566	.566	5.35	
104					978	57.24	1035.24		82	4.77	6465		775800	429624	.553			
105					1081	59.05	1140.05		93	4.20	7320		878400	473120	.538			
106	1.54	3.47	4.72	1.75	669	51.81	720.81	41.5	49	7.98	4450	12.00	534000	299136	.560			
107					772	53.62	825.62		55	7.10	4975		597000	342632	.574			
108					875	55.43	930.43		62	6.30	5575		669000	386128	.577			
109					978	57.24	1035.24		68	5.75	6150		738000	429624	.582	.582	5.75	
110					1081	59.05	1140.05		79	4.95	7025		843000	473120	.561			
111	1.54	3.47	4.72	2.00	978	57.24	1035.24	41.5	58	6.73	6075	12.00	729000	429624	.589			
112					1081	59.05	1140.05		62	6.30	6675		801000	473120	.590	.590	6.30	
113					1184	60.86	1244.86		72	5.43	7375		885000	516617	.583			
114	1.29	3.22	4.47	1.00	463	48.19	511.19	41.5	70	5.58	3545	11.75	416537	212144	.509			
115					566	50.00	616.00		82	4.77	4150		487625	255640	.524	.524	4.77	
116					669	51.81	720.81		96	4.07	4890		574575	299136	.521			
117	1.29	3.22	4.47	1.50	566	50.00	616.00	41.5	72	5.43	4075	11.75	478812	255640	.533			
118					669	51.81	720.81		78	5.01	4700		552250	299136	.542	.542	5.01	
119					772	53.62	825.62		94	4.16	5500		646250	342632	.530			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	

TABLE L.—PART I.

CHUTE No. 5.—*Elbow buckets. Close breast. Bottom of gate 7 feet above bottom of wheel.*

No. of Exper't.	Head of water above.			Width of Aperture.	Weight raised.	Friction.	Sum of friction and weight raised.	Height raised.	Time.	Velocity per second.	Wt of water expended.	Head and fall.	Power.	Effect.	Ratio, power being 1.	Maximum effect.	Velocity at maximum.	Observations.
	Btm. of gate.	Top of bkt.	Btm of bkt.															
	Feet.	Feet.	Feet.	In.	Pds.	Pounds	Pounds.	Feet.	Scds.	Feet.	Pds.	Feet.						
1	7.75	9.33	10.41	1.50	566	48.95	614.95	41.5	33	11.84	5425	14.75	800187	255204	.319			
2					669	50.58	719.58		36	10.86	6075		896062	298624	.333	.333	10.86	
3					772	52.21	824.21		42	9.31	7025		1036187	342046	.330			
4					875	53.84	928.84		49	7.98	8175		1206812	385468	.319			
5	7.00	8.58	9.66	1.50	566	48.95	614.95	51.5	34	11.50	5505	14.00	770700	255204	.330			
6					669	50.58	719.58		38	10.28	6230		872200	298624	.342	.342	10.38	
7					772	52.21	824.21		44	8.88	7225		1011500	342046	.338			
8	7.00	8.58	9.66	1.75	566	48.95	614.95	41.5	32	12.20	5350	14.00	749000	255204	.340			
9					669	50.58	719.58		34	11.50	5925		829500	298624	.359			
10					772	52.21	824.21		39	10.02	6735		942900	342046	.362	.362	10.02	
11					875	53.84	928.84		45	8.71	7880		1103200	385468	.349			
12					978	55.47	1033.47		51	7.66	8880		1243200	428889	.345			
13	6.00	7.58	8.66	1.50	566	48.95	614.95	41.5	40	9.77	5700	13. 0	741000	255204	.344			
14					669	50.58	719.58		41	9.54	6300		819000	298624	.364	.364	9.54	
15					772	52.21	824.21		49	7.98	7525		978250	342046	.349			
16	6.00	7.58	8.66	1.75	669	50.58	719.58	41.5	37	10.57	6075	13.00	789750	298624	.378	.378	10.57	
17					772	52.21	824.21		44	8.88	7050		916500	342046	.373			
18					875	53.84	928.84		50	7.82	8230		1069900	385468	.360			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	

Table L.—Part II.

Chute No. 4.—*Elbow buckets. Close breast. Bottom of gate 7 feet above bottom of wheel.*

No. of Exper't.	Head of water above.			Width of Aperture.	Weight raised.	Friction.	Sum of friction and weight raised.	Height raised.	Time.	Velocity per second.	W't of water expended.	Head and fall.	Power.	Effect.	Ratio, power being 1.	Maximum effect.	Velocity at maximum.	Observations.
	Btm. of gate.	Top of bkt.	Btm. of bkt.															
	Feet.	Feet.	Feet.	In.	Pds.	Pounds	Pounds.	Feet.	Scds.	Feet.	Pds.	Feet.						
19	6.00	7.58	8.66	2.00	566	48.95	614.95	41.5	31	12.60	5400	13.00	702000	255204	.363			
20					669	50.58	719.58		35	11.16	5950		773500	298624	.386	.386	11.16	
21					772	52.21	824.21		40	9.77	6950		903500	342046	.378			
22	5.00	6.58	7.66	1.25	566	48.95	614.95	41.5	46	8.50	5850	12.00	702000	255204	.363	.363	8.50	
23					669	50.58	719.58		56	6.98	7165		859800	298624	.347			
24	5.00	6.58	7.66	1.50	669	50.58	719.58	41.5	46	8.50	6490	12.0	778800	298624	.383	.383	8.50	
25					772	52.21	824.21		55	7.10	7950		954000	342046	.359			
26	5.00	6.58	7.66	1.75	772	52.21	824.21	41.5	49	7.98	7510	12.00	901200	342046	.379	.379	7.98	
27					875	53.84	928.84		58	6.74	8580		1029600	385468	.374			
28	5.00	6.58	7.66	2.00	669	50.58	719.58	41.5	39	10.02	6135	12.00	736200	298426	.405	.405	10.02	
29					875	53.84	928.84		54	7.24	8425		1011000	385468	.381			
30	4.00	5.58	6.66	1.00	360	46.61	406.61	41.5	46	8.50	4525	11.00	497750	168743	.339			
31					463	48.48	511.48		54	7.24	5350		588500	212264	.360	.360	7.24	
32					566	50.35	616.35		68	5.75	6500		715000	255785	.357			
33	4.00	5.58	6.66	1.50	463	48.48	511.48	41.5	38	10.28	5050	11.00	555500	212264	.382			
34					566	50.35	616.35		43	9.09	5675		624250	255785	409	.409	9.09	
35					669	52.22	721.22		52	7.52	6800		748000	299306	.400			
36					772	50.09	826.09		64	6.10	8350		918500	342827	.373			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	

Table L.—Part III.

Chute No. 5.—*Elbow buckets. Close breast. Bottom of gate 7 feet above bottom of wheel.*

No. of Expr't.	Head of water above.			Width of Aperture.	Weight raised.	Friction.	Sum of friction and weight raised.	Height raised.	Time.	Velocity per second.	W't of water expended.	Head and fall.	Power.	Effect.	Ratio, power being 1.	Maximum effect.	Velocity at maximum.	Observations.
	Btm. of gate.	Top of bkt.	Btm. of bkt.															
	Feet.	Feet.	Feet.	In.	Pds.	Pounds.	Pounds.	Feet.	Scds.	Feet.	Pds.	Feet.						
37	3.00	4.58	5.56	1.50	463	48.48	511.48	41.5	41	9.54	5000	10.00	500000	212264	.425			
38					566	50.35	616.35		49	7.98	5800		580000	255785	.441	.441	7.98	
39					669	52.22	721.22		57	6.86	6900		690000	299306	.433			
40	3.00	4.58	5.66	1.75	566	50.35	616.35	41.5	44	8.88	5575	10. 0	557500	255785	.459	.459	8.88	
41					669	52.22	721.22		52	7.52	6650		665000	299306	.450			
42					772	54.09	826.09		64	6.10	8100		810000	342827	.423			
43	3.00	4.58	5.66	2.00	566	50.35	616.35	41.5	42	9.31	5500	10.00	550000	255785	.465	.465	9.31	
44					669	52.22	721.22		51	7.66	6700		670000	299306	.447			
45	2.00	3.58	4.66	1.00	257	44.74	301.74	41.5	51	7.66	3125	9.00	281250	125222	.445			
46					360	46.61	406.61		66	5.92	4025		362250	168743	.466	.466	5.92	
47					463	48.48	511.48		85	4.60	5225		470250	212264	.451			
48	2.00	3.58	4.66	1.25	257	44.74	301.74	41.5	40	9.77	3800	9.00	342000	125222	.366			
49					463	48.48	511.48		60	6.50	5175		465750	212264	.455	.455	6.50	
50					566	50.35	616.35		67	5.84	6450		580500	255785	.440			
51					669	52.22	721.22		81	4.83	7675		690750	299306	.433			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	